No. 10. JULY. 1906.

Bi-Monthly Bulletin

OF THE

American Institute of Mining Engineers.

PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS

At S-W. Cor. Seventh and Cherry Sts.

PHILADELPHIA, PA.

EDITORIAL OFFICE AT 99 JOHN STREET, NEW YORK, N. Y.

Entered December 6, 1904, at Philadelphia, Pa., as second-class matter under Act of Congress of July 16, 1894.

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SECTION I.

INSTITUTE ANNOUNCEMENTS.

This section contains announcements of general interest to the members of the Institute, but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions*.

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* SECRETARY'S NOTE.—The Council is the professional body, having charge of the election of members, the holding of meetings (except business meetings), and the publication of papers, proceedings, etc. The Board of Directors is the body legally responsible for the business management of the Corporation, and is therefore, for convenience, composed of members residing in New York.

BI-MONTHLY BULLETIN.

For the convenience of persons who desire to file, or otherwise use separately, the technical papers in Section II. of the Bulletin, each of these papers has been paged and wired by itself; the whole collection being held together by a single, heavy wire, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

All communications concerning the contents of this Bulletin should be addressed to Dr. Joseph Struthers, Assistant Secretary and Editor, 99 John St., New York City (P. O. Box 223; Telephone number 5477 John).

UNITED ENGINEERING SOCIETY BUILDING.

Having given in successive numbers of the *Bi-Monthly Bulletin*, some account of the progress of the new home for the Engineering Societies, we find satisfaction in noting that, thus far, the promises of the architects and builders seem to have been fulfilled.

The Engineering Building structure is now enclosed, roofed and has the partitions in place, and the present report of progress seems a fitting place to draw attention to features of construction which have especially impressed the writer, who has closely followed the erection of the building.

Foundations were carried down in some cases 67 ft. to secure a hard rock-footing.

Two of these footings sustain a weight of 3,000,000 lb. each (in weight of structure alone), and the columns at these two points weigh 1,000 lb. to the foot.

The varied uses to which the building will be put have made both the design and construction very complicated.

The specifications, covering some 165 pages of foolscap, are dry reading, but attest to the fact that the architects, Herbert D. Hale and H. G. Morse, associate, gave much time and thought to the smallest detail.

Quite as important, however, as the drawing up of the plans and specifications has been the thorough way in which Wells' Brothers, the contractors, have carried on the construction under the close personal inspection of Mr. Morse. In fact, every one connected with the building of this home of engineering—architects, builders, sub-contractors, and even foremen and workers—have displayed a distinct pride in making it a fitting home for the professions.

The societies owe much to Mr. Charles T. Scott, Past President of the American Institute of Electrical Engineers, who has acted from the first as Chairman of the Engineering Building Committee, and as the active member of the Building Committee proper. Though a resident of Pittsburgh, Mr. Scott has

VIEW OF THE UNITED ENGINEERING SOCIETY BUILDING, NOS. 25 TO 33 WEST 39TH ST., NEW YORK CITY, TAKEN JULY 3, 1906.

made many trips to New York, and has devoted much time both to the study of plans and to watching the erection of the building.

The accompanying photograph was taken July 3d. It shows the imposing character of the building, and the fact that the treatment of the side-walls is in harmony with the front façade makes it one of the most noteworthy buildings in New York. All four sides are constructed of hydraulic-pressed, gray mottled brick, with limestone and terra-cotta trimmings. The interior construction is of the most substantial character, and the fire-risk has been reduced to the lowest limit. The floors are of 6-in. segmental semi-porous terra-cotta, overlaid with 5 in. of cinder-concrete. All furring and soffit tiles are 2 in. thick, and cover every beam and girder. An additional fire-protection is afforded by a metal-lathe type of ceiling suspended 2 in. below the floor-beams.

No wooden floors will be used except in lecture-rooms, and all window frames and cases are metal or metal covered. Exposed windows up to 100 ft. are fitted with wire-glass, as are also the elevator-grills.

The auditorium and lecture-halls are equipped with hot and cold water outlets on the stage, compressed air and electrical conduits for high and low potential currents for demonstration work. There are also exhaust hoods for chemical work. In these rooms the lighting is entirely by concealed electric lamps. In the offices, the ceilings are panelled with an electric-wire moulding of special design, which permits tapping in of lights at any point.

The report of progress, July 7, 1906, is as follows:—

1. All structural work completed.
2. All floors and partitions in place, finished plastering underway.
3. All risers—water, steam, electric, etc.—in place.
4. All stairways in place.
5. Elevators running or in place.
6. Boilers all set.
7. Some windows ready to be set in.

THEODORE DWIGHT,
Engineering Building Committee.

LIBRARY.

Accessions.

From May 8 to June 22, 1906.

American Smelting & Refining Company (through A. Eilers).

Berg und Hüttenmännische Zeitung. 4to. 1879, '82, '87–'93, '95, '97–1901.

Jahrbuch für Berg und Hüttenwesen. 4to. 1896–'99, 1901.

Zeitschrift für Berg, Hütten und Salinenwesen. 4to. 1874–'90, '92–'93, '95.

A. Bagel.

Jahrbuch für das Eisenhüttenwesen, 1903. Vol. 4. 8vo. Düsseldorf, 1906.

Century Association, New York, N. Y.

CENTURY ASSOCIATION. *Constitution and List of Members,* 1906. 12mo. New York, 1906.

Conservatoire National des Arts et Métiers.

FRANCE—MINISTÈRE DU COMMERCE, de L'INDUSTRIE, des POSTES et des TÉLÉGRAPHES. *Catalogue Officiel des Collections du Conservatoire National des Arts et Métiers.* Pt. 2. 8vo. Paris, 1905.

——— ——— *Enseignement des Sciences Appliquées aux Arts et à l'Industrie.* Programmes des Cours Publics. 280, 1 p. 8vo. Paris [1905].

Engineering and Mining Journal.

AMERICAN IRON AND STEEL ASSOCIATION. Compiler. *History of the Manufacture of Armor Plate for the U. S. Navy.* 33 p. 8vo. Philadelphia, 1899.

BERGMANNISCHE VEREIN ZU FREIBERG. *Freiberg's Berg- und Hüttenwesen. . . .* Ed. 2. viii, 340, 4p. pl. map, 8vo. Freiberg in Sachsen, 1893.

BORCHERS, DR. WILHELM. *Das neue Institut für Metallhüttenwesen und Elektrometallurgie* an der Königlichen Technischen Hochschule zu Aachen. 61p. 4to. Haale, A. S., 1903.

Engineering and Mining Journal (*continued*).

COHN, DR. PAUL. *Die Chemische Industrie.* 112 p. 4to. (Weltausstellung, St. Louis, 1904).

DAMOUR, EMILIO. *Industrial Furnaces and Methods of Control. . . .* Authorized translation, with additions, by A. J. L. Queneau. Ed. 1. xvi, 317 p. il. pl. 8vo. New York, 1906. $4.00.

[SECRETARY'S NOTE.—This translation of Damour's "*Le Chauffage Industriel et les Fours à Gas*" comprises not only the contents of that important treatise, but much additional material, of great practical value to American metallurgists. Under this head may be specially mentioned the discussions of pyrometry, calorimetry, and gas- and fuel-analysis,—subjects but slightly touched in the original treatise. Besides these additions, the book has been enriched with diagrams, plates, tables and illustrative problems. The result reflects much credit upon Mr. Queneau, the translator and editor, and upon the *Engineering and Mining Journal*, which has published the book in excellent style.—R. W. R.]

DREDGE, JAMES. *Dedication of the Holley Memorial, New York*, October, 1890, with the Memorial Address. 41 p. pl. 4to. New York, 1892.

EBERLE, CHR. *Kosten der Krafterzeugung.* 56 p. 4to. Haale, A. S., 1898.

JAMES, E. *L'Horlogérie.* xi, 228 p. 12mo. Paris, 1906.

NATAL—SURVEYOR-GENERAL'S DEPARTMENT. *Second Report of the Geological Survey of Natal and Zululand*, by William Anderson. 4to. London, 1904.

172 pamphlets were also received from E. & M. J.

Institution of Mining and Metallurgy, London.

INSTITUTION OF MINING AND METALLURGY. *Bulletin* No. 20. 8vo.

BRACKENBURY, C. *Some Copper Deposits in Rhodesia.* 10 p. 8vo.

GREGORY, J. W. *The Ancient Auriferous Conglomerates of Southern Rhodesia.* 16 p. pl. map. 8vo.

JARMAN, A. *A New Form of Platinum Parting Apparatus.* 16 p. il. 8vo.

PARSONS, C. E. *Huntington Mill Notes.* 26 p. il. 8vo.

TERRY, H. L. *Chert Mining in England and Wales.* 10 p. 8vo.

Iron Age.

Iron Age Directory. Ed. 10. 16mo. New York, 1906.

Iron and Steel Institute, London.

ADAMSON, E. *Influence of Silicon, Phosphorus, Manganese and Aluminum on Chill in Cast-Iron.* 24 p. pl. 8vo.

ARNOLD, J. O. and KNOWLES, F. K. *Preliminary Note on the Influence of Manganese on Iron.* 8 p. 8vo.

BANNISTER, C. O. *The Relation Between Type of Fracture and Micro-Structure of Steel Test-Pieces.* 16 p. pl. 8vo.

CAPRON, A. J. *Compression of Steel Ingots in the Mould.* 8 p. il. pl. 8vo.

EYERMANN, P. *Solid Rolled Steel Car Wheels and Tires.* 31 p. il. pl. 8vo.

LAW, E. F. *Brittleness and Blisters in Thin Steel Sheets.* 12 p. il. 8vo.

LELONG, E. *Chain-Making Machinery.* 11 p. il. pl. 8vo.

SCHWARZ, C. DE. *Use of Oxygen in Removing Blast-Furnace Obstructions.* 8 p. il. 8vo.

TURNER, T. *Volume and Temperature Changes During the Cooling of Cast-Iron.* 20 p. il. 8vo.

WIGHAM, F. H. *The Effect of Copper in Steel.* 12 p. 8vo.

J. S. Jeans.

BRITISH IRON TRADE ASSOCIATION. *Annual Statistical Report*, 1903, 1904. 8vo. London [1904, 1905].

JEANS, J. S. *Canada's Resources and Possibilities.* xv, 298 p. 8vo. London, 1904.

K. K. Ackerbauministerium.

AUSTRIA—K. K. ACKERBAUMINISTERIUM. *Durchschnittsleistungen der Grubenarbeiter beim Kohlenbergbau Osterreichs* in den Jahren, 1901, 1903 und 1904. 19 p. 8vo. Wien, 1906.

George F. Kunz.

KUNZ, G. F. *Gems, Jewelers' Materials and Ornamental Stones of California.* 171 p. il. pl. 8vo. Sacramento, 1905. (California—State Mining Bureau. *Bulletin*, No. 37).

——— *Catalogue of the Tiffany and Company Collection of Jade and Rock Crystal.* 87 p. 12mo. New York, 1899.

——— *Natal Stones, Sentiment and Superstition Connected with Precious Stones.* 31 p. 16mo. New York, n. d.

——— *A New Lilac-Colored Spodumene from Pala, California.* p. 264–267. 8vo. n. p., no. d.

George F. Kunz (*continued*).

KUNZ, G. F. *Printed Catalogue of the Heber R. Bishop Collection of Jade in the Metropolitan Museum of Art.* 8 p. il. 8vo. New York, 1906.

——— *Production of Precious Stones in the United States.* Reprinted from the Reports of the Department of Mining Statistics, U. S. Geological Survey, for 1895, 1896, 1897, 1898, 1899. pl. 4to. Washington, 1900.

——— ——— 1900–1904. 5 pts. 8vo. Washington, 1901–1905.

TIFFANY AND COMPANY. *Collection of Pearls.* 16p. 12mo. New York, 1900.

C. K. Leith.

LEITH, C. K. *Iron-Ore Reserves.* p. 360–368. 8vo.

McGraw Publishing Company.

HOWE, H. M. *Iron, Steel, and Other Alloys.* Ed. 2. xviii, 495 p. il. pl. 8vo. Cambridge, 1906. $5.00.

[SECRETARY'S NOTE.—It is not necessary to emphasize the great interest and value of this contribution to modern metallography by one of the leaders in that field. Prof. Howe is not only an original experimenter, but also a learned and intelligent compiler and critic of the work of others. It is an old story that the best books of this class are usually issued by Professors, not only because they are most likely to be competent, but also, and especially, because the regular duties which they are already paid to perform involve that examination and valuation of current technical works which other authors must make at their own expense. Prof. Howe, who prepared this book primarily for the use of his own students at Columbia University, has been assisted in its revision and publication by several accomplished experts in different departments. This second edition (the first having appeared in 1903) contains, as new material, the classification and definition of iron and steel prepared by Profs. Howe and Sauveur for the International Association for Testing Materials, and also descriptions of the Roe puddler, the Mond gas-producer, and the Gayley dry-blast process. Moreover, the discussion of the transitional compounds, martensite, troostite and sorbite, has been rewritten.—R. W. R.]

Minister of Mines of British Columbia.

BRITISH COLUMBIA MINES DEPARTMENT. *Annual Report,* 1905. 8vo. Victoria, 1906.

Natal—Commissioner of Mines.

NATAL—MINES DEPARTMENT. *Report of the Mining Industry,* 1904. f°. Pietermaritzburg, 1905.

New South Wales—Department of Mines and Agriculture.

ANDREWS, E. C. *Molybdenum.* 17 p. il. pl. 8vo. Sydney, 1906.

Norman W. Henley & Company.

WOODWORTH, J. V. *Hardening, Tempering, Annealing and Forging of Steel.* 288p. il. 8vo. New York, 1903. $2.50.

[SECRETARY'S NOTE.—Practicing engineers are well aware that there are two sciences—that is to say, two collections of known and more or less understood facts—in many departments of their profession, namely, the facts recorded, arranged and explained in the books, and the facts recognized and habitually utilized in the shops. The latter, indeed, constitute the primary source of information. Practice is always ahead of theory; yet it is only right that the experiences of practice should be verified, sifted, critically weighed and classified, before they are adopted as bases for theoretical generalizations and formulas. For the facilitation of this necessary process, nothing is more directly valuable than the reports of practice, made by men not ignorant of accepted theory, and competent to record the facts with intelligence and accuracy. To this class, the present book characteristically belongs. It treats, from the standpoint of the shop, of the selection and manipulation, for various purposes, of various brands and kinds of steel, including the details of annealing, hardening, tempering, general heat-treatment, welding, forging, grinding and lathe-work; and its very plain and clear descriptions are complemented with numerous admirable illustrations, as well as useful formulas and tables.—R. W. R.]

Philippine Islands Mining Bureau.

SMITH, W. D. *The Coal Deposits of Batan Island, with Notes on the General and Economic Geology of the Adjacent Region.* 56p. pl. maps. 8vo. Manila, 1905. (*Bulletin*, No. 5.)

R. W. Raymond.

KEIM, DE B. R. *Sherman. A Memorial in Art, Oratory, and Literature.* 410 p. 4to. Washington, 1904.

HEINRICHS, G. D. *Absolute Atomic Weights.* xvi, 303, 1 p. 8vo. St. Louis, 1901.

J. W. Richards.

RICHARDS, J. W. *Metallurgical Calculations.* 201p. 8vo. New York, 1906. $2.00 *net.*

[SECRETARY'S NOTE.—The work of which this volume constitutes the first part bids fair to fill satisfactorily the place, so often assumed by ambitious authors to exist, of a "long-felt want." In the present instance, the want is real and pressing, and is felt by instructors, pupils, private students and experienced practitioners alike. The importance which thermal calculations, in particular, have acquired in recent years has rendered a knowledge of both the methods and the data of such calculations imperatively necessary to all metallurgists; and the present treatise, while it attacks the subject from the side of theory and method the only proper way of beginning), and is largely occupied with problems for the use of students, contains also many tabulated results of observation, which even experts are obliged to seek separately in monographs scattered through

technical journals. It is to be confidently hoped that the succeeding instalments of this work will contain additional tables, furnishing the student with a comprehensive, trustworthy body of material, as well as intelligent guidance in its use. Nothing in the field of modern metallurgy would be more universally welcome; and nobody is better qualified to prepare it than Professor Richards.—R. W. R.]

C. H. Shamel.

SHAMEL, C. H. *The American Law Relating to Minerals.* 27 p. 8vo. n.p., n.d.

Société Ingénieurs Civils de France.

SOCIÉTÉ INGÉNIEURS CIVILS DE FRANCE. *Table Générale des Matières.* Contènues dans les Bulletins de la Société. 1885–1904. 8vo. Paris, 1905.

Society of Engineers, London.

SOCIETY OF ENGINEERS. *Transactions*, 1905. 8vo. London, 1906.

U. S. Geological Survey.

ARNOLD, RALPH. *The Tertiary and Quaternary Peetens of California.* 264 p. pl. 4to. Washington, 1906. (Professional Paper, No. 47.)

BROOKS, A. H. *Geography and Geology of Alaska.* 327 p. pl. maps. 4to. Washington, 1906. (Professional Paper, No. 45.)

ASHLEY, G. H. and GLENN, L. C. *Geology and Mineral Resources of Part of the Cumberland Gap Coal Field, Kentucky.* 239 p. il. pl. maps. 4to. Washington, 1906. (Professional Paper, No. 49.)

PRINDLE, L. M. and HESS, F. L. *The Rampart Gold Placer Region, Alaska.* 54 p. pl. maps. 8vo. Washington, 1906. (*Bulletin*, No. 280.)

U. S. GEOLOGICAL SURVEY. *Report on the Operation of the Coal Testing Plant of the United States Geological Survey at the Louisiana Purchase Exposition*, St. Louis, Mo., 1904. 3 pts. 4to. Washington, 1906. (Professional Paper, No. 48.) Contents: Pt. I.—Field Work, Classification of Coals, Chemical Work. Pt. II.—Boiler Tests. Pt. III.—Producer Gas, Coking, Briquetting and Washing Tests.

J. F. Wallace.

U. S. SENATE. *Isthmian Canal.* v. p. 8vo. Washington, 1906.

PURCHASES.

ROYAL SOCIETY OF LONDON. *Catalogue of Scientific Papers.* Vols. 10–12. 4to. London, 1894, 1896, 1902.

CHEMICAL SOCIETY OF LONDON. *Collective Index to Proceedings,* 1893–1902. Vols. 1–2. 8vo. London, n. d.

FISCHER, F. *Jahres Bericht über die Leistungen der Chemischen Technologie.* Vol. 51, new ser. 36. Organischer Theil. 8vo. Leipzig, 1906.

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The following list comprises the names of those persons elected as Members or Associates, who duly accepted election during May and June, 1906:—

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Date of Election.	Name.	Date of Decease.
1888.	*Richard J. Seddon.	June 10, 1906.

* Member.

SECTION II.

TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

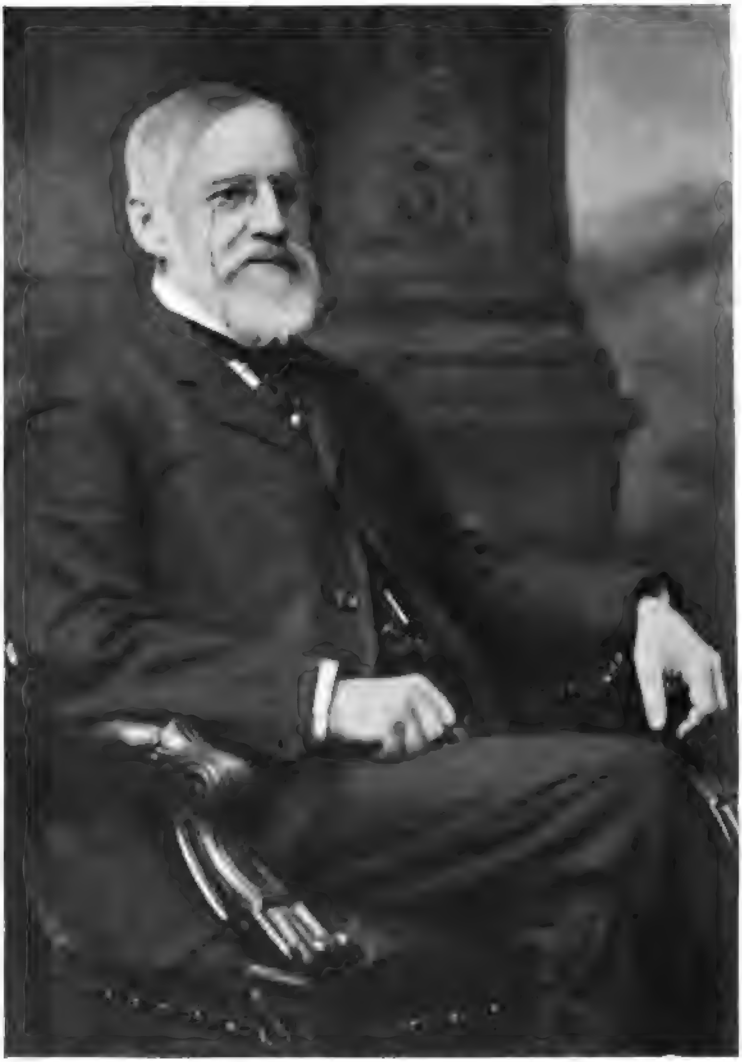
A detailed list of the papers contained in this section is given in the Table of Contents, pages i and ii.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

ERRATUM.

Correction to *Bi-Monthly Bulletin*, No. 9, May, 1906.

Page.	Line.	
vii	29	for "February 14, 1906," read "February 14, 1904."



[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Biographical Notice of Edward Cooper.

BY R. W. RAYMOND, NEW YORK, N. Y.

(Bethlehem Meeting, February, 1906.)

EDWARD COOPER was born in New York City, October 26, 1824. His father, Peter Cooper, to say nothing of manifold reasons for fame as an inventor and philanthropist, deserves to be remembered as a pioneer in the establishment of public schools; and it is not surprising that he sent his son to one of the democratic institutions in which he was himself so ardently interested. From the public school Edward Cooper went to Columbia College, where he made the acquaintance of Abram S. Hewitt, who was first his tutor, afterwards his traveling companion, brother-in-law, business partner and life-long friend.*

For twenty years I was the consulting engineer of the firm of Cooper & Hewitt, and also connected with the work of the Cooper Union, in which they were both deeply interested and faithfully active. On the basis of the intimate knowledge thus gained, I venture an estimate of Edward Cooper's character and career which, if not fully comprehensive, may facilitate a juster estimate than would be reached by the student of those data which the modesty of the man permitted to be placed upon public record.

Edward Cooper's mind was one of the most active, accurate and subtle with which I have ever come into contact. He had inherited from his father a sunny, benevolent temperament, and the irresistible impulse to attack all new problems which challenged his attention. His thorough education had indeed made him wiser than his father, both in philanthropy and in technical inventions. He could condemn and reject a proposition which Peter Cooper would have embraced, in a splendid, though ignorant, faith that nothing was impossible to an American, and that the word "impossible" was simply a label,

* See, for further particulars of their early association, my "Biographical Notice of Abram S. Hewitt," *Trans.*, xxxiv., 186.

put upon things reserved for the citizens of the Republic to achieve. The son's greater knowledge led him to see clearly both sides of a proposition, where the father saw but one. Yet it remained his leading characteristic, that he loved to study, criticize and invent, rather than to conclude, adopt and execute. When he had exhausted a question, he was prone to drop it. So long as it called for further inquiries, he was indisposed to settle it by any final decision.

I have often fancied that one who enjoyed, and utilized, the opportunity to pick up and put into practical application the ideas, suggestions and investigations of Edward Cooper, might attain thereby the fame and fortune to which Mr. Cooper himself seemed indifferent.

As an instance of his passion for intense intellectual labor upon a subject which interested him, I remember a copy of the English translation of Prof. Grüner's work on the thermal reactions of the blast-furnace. The book is full of disgraceful errors in the calculation and printing of equations and tables. Having occasion one day to consult Mr. Cooper's copy, I found that he had laboriously corrected it, from beginning to end, simply for his own satisfaction!

Sometimes (as in the cases of the Durham blast-furnace charging-apparatus and hot-blast stoves*) he utilized his scientific ability and inventive genius in useful inventions; but I do not think he ever applied for a patent.

He was deeply interested in the attempts of Chenot and others to produce iron-sponge by the direct reduction of iron-oxide ores; and, as early as 1863 or 1864, he instituted at the Andover furnace, Phillipsburg, N. J., experiments in the reduction of iron-ore, without fusion, by means of heated carbon monoxide, forced through a chamber containing carefully selected and broken ores. According to the recollection of Mr. Joseph C. Kent, then and for many years afterwards the manager of the Andover works, this experiment failed by reason of a siliceous dust which, accumulating in the interstices of the finely-broken charge, coated the pieces of ore with a tenacious film, effectually preventing the deoxidizing action of the carbon monoxide. If this was the only difficulty, it could scarcely be

* *Trans.*, xiv., 130, and xxxv., 582.

regarded as insuperable; and, in fact, Mr. Kent remembers that Mr. Cooper said he could probably devise some way of overcoming it. Probably he dropped the subject for a while. At all events, nothing more was done in that line at Phillipsburg; and in 1867, when the works at Phillipsburg were sold by Cooper & Hewitt to the Andover Iron Co., parts of Mr. Cooper's direct-reduction apparatus were shipped, as possibly available for further experiments, to the Durham Iron Works, Ridgeville, Pa., owned by the firm. Mr. B. F. Fackenthal, Jr., subsequently for many years the manager of the Durham Iron Works, remembers these pieces as embodying novel details (especially in the construction of gas-valves, etc.), which have since been universally adopted. With his usual indifference to personal credit or reward, Mr. Cooper made no claim to them as his inventions.

Meanwhile, he continued to pursue with intense interest and unwearied study the subject of thermal physics and chemistry, particularly as related to the use of gaseous fuel, the Siemens regenerator, etc.; and I remember finding in his office a pile of sheets, covered with figures which represented his elaborate and minute calculations, performed at home and at night (for I never saw him so employed at his office), and antedating much that was subsequently published by others.

As a result of these studies, he began, about 1873, at the works of the New Jersey Steel and Iron Company (Cooper, Hewitt & Co.), at Trenton, N. J., the practical test of a direct-reduction process, which presented many novel features of his own. The principles of this process have been deemed worthy of special recognition by Prof. H. M. Howe, whose classic work contains a description of it, with a diagram illustrating the apparatus.* In this process, to quote the preliminary summary there given:

"Iron ore is heated and reduced by a current of hot carbonic oxide, or carbonic oxide and hydrogen. These gases are oxidized to carbonic acid and steam by the oxygen of the ore; they are then passed through a regenerator, in which they are highly heated, and thence through a bed of coal or other fuel, in which they are again deoxidized to carbonic oxide and hydrogen. Still remaining in the same closed circuit, they are then used for reducing a fresh portion of ore, a part of the carbonic oxide and hydrogen, however, being diverted to heat the regenerator already mentioned.

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* *The Metallurgy of Steel*, vol. i., 2d ed. New York, 1891, pp. 275, 276.

To simplify matters, let us suppose that only carbonic oxide is used, and follow the course of the gas. What is true of pure carbonic oxide would be true of a mixture of this gas with hydrogen, mutatis mutandis."

After giving the calorific calculations involved upon the above assumption, which showed a theoretical excess of heat above the amount required for the chemical reactions, and thus available to make up the loss by radiation, to heat the ore to the temperature of deoxidation, etc., Prof. Howe continues:

"This, in Mr. Cooper's opinion, is not a sufficient surplus. Hence he introduces steam along with the carbonic acid into the regenerator and thence into the gas-producer, thus making water-gas, and thus increasing the quantity of gas available for burning in the regenerator, but without introducing nitrogen into the closed circuit of the reducing system. It may, indeed, be regarded as a mode of making water-gas, which is used while still hot from the gas-producer for deoxidizing iron-ore. The steam is introduced in the form of a jet, and incidentally aids the circulation of the gas through the system."

I forbear to quote further from Prof. Howe's description, which is accessible to all interested students of the subject. Though confessedly incomplete as a statement of the somewhat complicated details of Mr. Cooper's apparatus, it clearly indicates that his scheme comprised many ingenious and novel features, and embodied a wonderfully complete plan for the utilization of the heat of all the chemical reactions of reduction and combustion involved.

Indeed, this theoretical completeness, and the consequent difficulty of constructing and operating the several parts of the experimental plant, proved to be one of the reasons for the final abandonment of the enterprise. Explosions due to leaks in flue-walls, and troubles with valves or other mechanical details, involved discouraging delays and fresh outlays for reconstruction, repair, or new design.

But these experiences, inseparable from such undertakings, did not disprove Mr. Cooper's theory, and would not have been sufficient to prevent him from persevering in his plan. Indirectly, however, they had a greater effect; for they delayed his experiments until the improvements in blast-furnace practice, already accomplished or clearly foreseen by his prophetic eye, forced upon him the conviction that the most perfect "direct process" would be unable to compete with the old method of combined reduction and fusion, producing pig-iron as a mate-

rial for further transformations. The simple circumstance that a "direct process" for the production of iron-sponge would require rich and pure iron-ore, and could be operated only upon a limited scale as to size of the unit of plant, was fatal to that whole class of processes. Theoretical gains in heat-economy dwindled and disappeared before the enormous savings effected in all departments of the manufacture of pig-iron by increase in the temperature and pressure of blast, in the dimensions and productive capacity of each furnace, and in facilities for the cheap handling of raw material and product.

It was characteristic of Edward Cooper that he did not, like many another inventor embarked upon a darling conception, refuse to recognize the controlling current which was leaving him in an eddy of self-centered revolution. On the contrary, with imperturbable good-nature, he said: "I fancy the blast-furnace is going to be the best thing, after all!" and, abandoning the problem of "direct reduction," upon which he had expended so much time, labor and money, turned his attention to other problems, equally attractive and apparently more practically important. During this last stage of his "direct-process" experiment, I was associated with him as the consulting engineer of his firm; and it was at his request that I communicated to Prof. Howe some of the data for the notice of Mr. Cooper's process, contained in *The Metallurgy of Steel.* I may, therefore, claim the authority of personal knowledge for the foregoing statements.

Mr. Cooper was a public-spirited citizen, and a supporter of all meritorious social and municipal movements. He was among those who supported Mr. Tilden in the overthrow of the "Tweed ring," and in 1879 he was elected Mayor of New York City, eight years before his partner, Mr. Hewitt, received that honor. Mr. Cooper's administration was hampered by many conditions from which his successors were freed by legislative action. He soon discovered that his power as Mayor was very small; but, instead of making that fact an excuse for sullen inactivity, he accepted the situation with characteristic good-nature, and patiently did what he could.

When his nominees for municipal office were rejected by the political body which then held, under the city charter, the power of confirmation, he smiled, and made other nominations.

But he thoroughly exposed, through the reports of his Commissioners of Accounts and otherwise, evils which, under the circumstances of that time, the Mayor lacked the power to attack directly and to remove. In my judgment, his administration planted the seeds of many reforms, of which his successors reaped the harvest. I know that, during that period, as before and after it, not only Mr. Hewitt, but many another conspicuous leader, freely sought and greatly valued his counsels.

It must not be inferred from his habitual gentleness and amiability that he was capable of surrendering his personal convictions of principle and duty. On the contrary, I think I never knew so immovably firm a will as that of this kindly, quiet, modest man, who would neither fight nor yield. I recall an important public occasion, when he stood, against all his political associates, a silent, undemonstrative, unconquerable minority of one; and, if it were permissible, I could give sundry other illustrations, both in politics and in business, of the steadfastness with which, against all persuasions, and at the sacrifice of personal interests, he held to his own convictions of right. Nobody could, and, so far as I am aware, nobody ever thought he could, fasten upon Edward Cooper the least charge or suspicion of unworthy motive. In a time of excited political activity and business competition, in both of which he was a by no means insignificant factor, he kept his honor without stain, either deserved through acts of his own, or undeserved, through the slanders or the doubts of others.

Mr. Cooper became a member of the Institute in 1874; and, although he left his own important contributions to American metallurgical and mechanical practice to be described in our *Transactions* by other writers, he maintained, to the time of his death, a hearty interest in the affairs of the Institute, and a cordial and helpful friendship for its members. During the twenty years of my business connection with him, as the engineer of the firm of Cooper & Hewitt, I enjoyed, through the generous agreement of both partners, a free permission to attend all the meetings of the Institute, and, for about ten years of the twenty, to discharge the duties of its Secretary, provided the interests of the firm of which I had charge were not allowed to suffer. Under this proviso, I consulted one or the other of them, as a matter of form, before going off for a week or more, to attend

an Institute meeting; but the matter was invariably referred back to me, for my own decision. I trust that this decision was always rendered with due regard to the interests of these generous employers. At all events, the fact that, out of ninety meetings of the Institute, I have been present at eighty-six, and that I attended, without objection, before or after the event, from either Mr. Cooper or Mr. Hewitt, all but one of the meetings which occurred during the twenty years of my business connection with them, is certainly significant.

Moreover, the firm leased to me, as Secretary, at the nominal rent of $800, practically two floors of one of the buildings occupied by their business. In the interior reconstructions involved in this arrangement, Mr. Cooper took the liveliest interest. The arrangement itself was continued for some years after I left the service of the firm, and was terminated only in 1899, when the work of the Institute demanded the removal of the Secretary's office to the commodious quarters which it now occupies.

I venture to relate here an incident, trifling in itself, but thoroughly characteristic of Edward Cooper. One day, after going over with me some matters of business, he said suddenly: "Raymond, I notice in one of your circulars a statement of the cost of life-membership. Now, I have been figuring on that matter; and I find that, in view of my age and normal expectation of life, the present value of an annuity of $10 would be less than the life-membership fee. Consequently, I do not consider life-membership as a good business investment. However, if the Institute wants the money, that is another question!" I assured him that the Institute did not want the money; and he lived thereafter long enough to pay in annual dues much more than the life-membership fee, with compound interest!

But perhaps the most characteristic service rendered to the Institute by Mr. Cooper is recognized in the following minute, adopted by the Council, March 13, 1905:

"Hon. Edward Cooper, who died February 25, 1905, in the 81st year of his age, had been for over thirty years an honored member of this Institute, having joined it, together with his partner and brother-in-law, Hon. Abram S. Hewitt, at a time when the encouragement and support of such men were vitally important to it.

"The pages of its *Transactions* show the value of his contributions to progress

in the metallurgy of iron, and his personal interest in the success of the Institute was evinced by his discharge, for many years, of the important, though not publicly proclaimed, duties of a member of its Finance Committee. To many of its members he was a cordial and helpful friend.

"His eminent services in national and municipal affairs, and his upright, generous and winning personal character, enhance both the just pride and the inevitable sorrow with which all who knew him in any of the manifold spheres of his beneficent activity now receive the tidings of his decease."

I treasure a pathetic letter from Mr. Cooper, written not long before his death, in which he requested to be released from the unostentatious but onerous duty of examining and certifying my monthly vouchers, on the sole ground that failing eye-sight prevented him from discharging it.

In common with a host of those who enjoyed the privilege of an acquaintance with Edward Cooper, and as one of the smaller number who were blessed with his daily companionship, I thank God for a life so pure, so unselfish, and so greatly useful to mankind.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Notes on the Roumanian Oil-Fields.

BY P. CHARTERIS A. STEWART, CAIRO, EGYPT.

(Bethlehem Meeting, February, 1906.)

THE following scanty notes on the Roumanian oil-region may serve as an introduction to more detailed future study and description.

The Roumanian oil-belt follows the outer edge of the sweep of the Carpathian Mountains, and may, in a broad sense, be regarded as a prolongation of the Galician belt. It is distributed over a tract of country from 300 to 400 miles in length, with a width of from 15 to 20 miles, and is believed to cover an area of at least 20,000 hectares (59,420 acres). The Government claims that 16,000 to 17,000 hectares of its land is petroliferous.

The primary deposits of petroleum are considered to be in the Paleogene (Oligocene) and the Neogene (the salines of the Miocene) formations. Most of the other repositories, especially those of Muntenie, are only secondary, the petroleum there having been introduced by the orogeneric movements which raised the Carpathian Mountains.

The oil-field has been divided by the Roumanian survey into two regions, the Flysch and the Sub-Carpathian, as is shown in the accompanying sketch-map, Fig. 1 (p. 518). So far as is yet known, practically all the seepages and productive pits and wells are situated on anticlinals.

Those which outcrop in the *Flysch region* (called Paleogene anticlinals), as indicated in the sketch-map, Fig. 1, are : *Solontz*, Middle Oligocene; *Moineshti*, Moineshti and Tagu-Ocna-beds of the Eocene.

Those of the *Sub-Carpathian* are :—

Prajol-Campeni, Saliferous Miocene;

Beciu-Bercea, Meotic, and a few Pontic beds;

Sarata Monteor, Nucleus of Sarmation with Pliocene on the flanks. Direction of anticlinal, SW. by W.;

Recea, Meotic, with a kernel of massive rock-salt;

Campina-Bustenari-Poiana, Meotic, with rock-salt masses in places. (The eastern end of Bustanari *Faget* is Oligocene.);

Calibasi, Nucleus of Saliferous Miocene with Sarmatian, Meotic, Pontic (Congeria beds), and in some parts Levantine (Unio Sculptée beds);

Baicoi-Tintea, Anticlinal of Pontic (Vivipara bifarcinata and Congeries beds), and Levantine, lying directly upon the Saliferous Miocene;

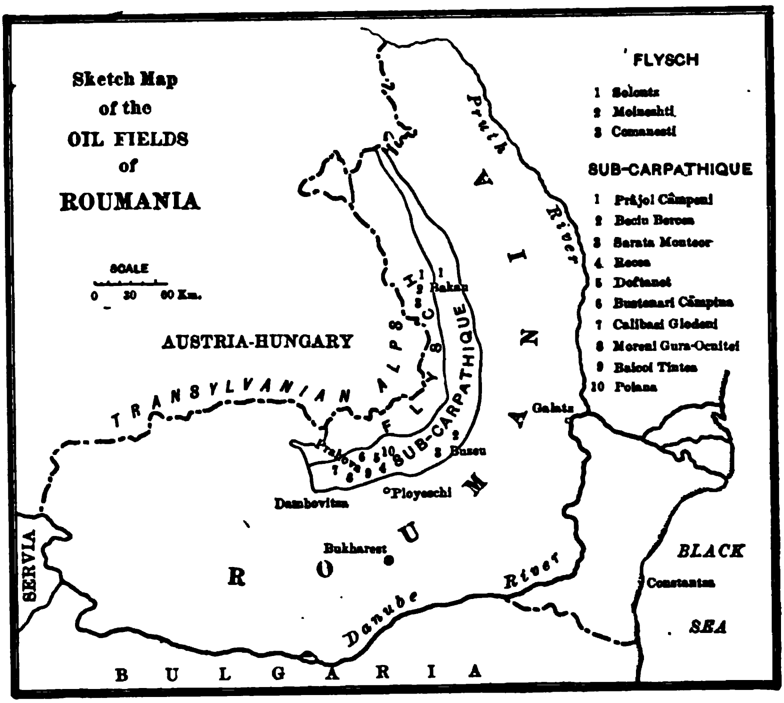

FIG. 1.—SKETCH-MAP OF ROUMANIAN OIL-FIELDS.

Moreni, *Gura-Ocnitei*, Anticlinal of Pontic (Congeries and Vivapara); Levantine (Unios sculptées and Candeshti beds), lying directly upon the Saline Miocene.

The oil of the Miocene is found on the sandy-marl *facies* in the immediate vicinity of the salt masses. The general impression gained is that large quantities of petroleum may be found accumulated in the anticlinals which have a kernel of massive salt.

Most of the anticlinals of the Sub-Carpathian region belong

to the Neogene epoch. They run more or less parallel with the main mountain-chain. Thus in the north, in Moldavia, their course is roughly N–S., while in the Prahova district it is more nearly ENE–WSW. By reason of the permeability of the grits and sands, the petroleum is generally contained in these rocks.

Erosion has, in some cases, carved deeply into the crowns of these anticlinals, laying bare the oil-strata, allowing the escape of oil and the ingress of water, with consequent flooding of the strata. In many places, the former impermeable covering is no longer found intact.

In the Flysch of Moldavia, some beds of which are supposed to be synchronous with those of Galicia, the relative absence of confined permeable beds seems to be the cause of a small production, as compared with that of Galicia. It is, however, possible that, more favorable conditions permitting, better results may be encountered in depth.

Numerous difficulties attend the drilling of wells in Roumania, the structure being, in many cases, very complicated. On the other hand, the Roumanians are inclined, in complaining of their own troubles, to underestimate the complexity of the strata and the difficulties of drilling in other parts of the world. The main obstacles with which Roumanians have to contend in drilling are: water, which must be shut out, and the breaking-off (after the removal of the oil-sand by the flow of oil and gas) of a hard, highly-inclined layer immediately above the oil-sand, which causes squeezing of the casing, and a caving of argillaceous bands directly overlying the oil-sand. Where the oil is found in overturned anticlinals, there is often a slipping along lamination-planes, which results in enormous pressures on the casing. Moreover, the occurrence of quicksands and of movements due to the removal of sand by the flowing gas and oil, may be the causes of disaster. To all these sources may be attributed many failures in the "getting down" of Roumanian wells.

There are about 87 localities where petroleum is known to exist; and of these, only about half-a-dozen have been anything like sufficiently exploited.

The figures in Tables I., II. and III. show that the Prahova district, with its production of 92.4 per cent., of which 82.3

per cent. comes from the two fields of Bustenari and Campina-Poiana, is by far the most important district in Roumania at the present time.

TABLE I.—*Production of Petroleum in Roumania from* 1895 *to* 1904 (*not Including the Quantity Used Locally for Fuel*).[a]

Year.	Metric Tons.	Year.	Metric Tons.
1895,	240	1901,	270,000
1896,	....	1902,	320,000
1897,	110,000	1903,	[b] 384,302
1898,	180,000	1904,	500,561
1899,	250,000	1905,	614,870
1900,	250,000		

[a] Reported by the *Moniteur de Pétrole Roumain.*

[b] The return given by the Special Commission for 1903 was 388,090 tons, probably including the oil used for fuel on the field.

TABLE II.—*Production of Petroleum in Roumania for* 1902, '03, *and* '04, *Classified by Fields* (*Metric Tons*).

<table>
<tr><th></th><th colspan="5">Prahova District.</th><th>Dambo-vitja.</th><th>Buzeu.</th><th>Bacau.</th></tr>
<tr><td>1902</td><td colspan="5">270,000</td><td>15,000</td><td>4,000</td><td>11,000</td></tr>
<tr><td>1903</td><td colspan="5">345,913</td><td>22,469</td><td>5,920</td><td>............</td></tr>
<tr><td></td><td>Bustenari.</td><td>Campina-Poiana.</td><td>Moreni.</td><td>Tintea.</td><td>Other Prahova Fields</td><td></td><td></td><td></td></tr>
<tr><td>1904</td><td>331,860</td><td>109,269</td><td>4,849</td><td>4,100</td><td>5,776</td><td>26,234</td><td>8,828</td><td>10,145</td></tr>
<tr><td>1905</td><td>411,407
(66.9%)</td><td>94,860
(15.4%)</td><td>47,243
(7.7%)</td><td>7,412
(1.2%)</td><td>7,871
(1.2%)</td><td>24,703</td><td>12,904</td><td>8,974</td></tr>
<tr><td></td><td colspan="5">(92.4%)</td><td>(4.0%)</td><td>(2.1%)</td><td>(1.5%)</td></tr>
</table>

TABLE III.—*Data of Wells and Pits During* 1905.[a]

	Wells.			Silts.		
	Producing.	Drilling.	Abandoned.	Producing.	Sinking.	Abandoned.
Prahova..........	266	197	142	276	70	723
Dambovitza......	10	13	10	93	21	145
Buzeu.............	8	....	28	67	16	168
Bacau.............	46	5	42	244	26	194
1905..............	330	215	222	680	133	1,132
1904..............	220	107	148	743	175	1,129
1903..............	190	92	118	675	163	997

[a] Reported by the *Moniteur de Pétrole Roumain.*

Campina Bustenari.—This zone, about 14 km. long, with undetermined but varying width, is formed of an anticlinal of Meotic beds jammed up against a fault which is the southern limit of the Sub-Carpathian saline series. A section of this zone is shown in Fig. 2.

The eastern part of this belt, Doftanetz Faget, is formed of an anticlinal in Oligocene beds. A section of this zone is shown in Fig. 3.

Campina.—The strike of the anticlinal is N. 60° E., the dip to S. is about 30°, that to N. nearly 70°. There are about seven recognized oil-sands on the south side, but they are not all of a paying quality. The northern limb is steep and short,

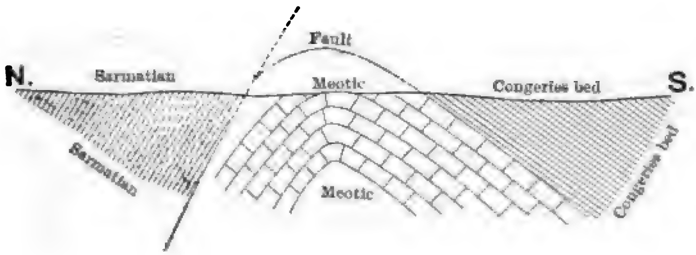

FIG. 2.—SECTION ACROSS OIL-ZONE AT CAMPINA.

being cut-off by the before-mentioned fault, causing the northern side to be of comparatively little value. This fault can be well seen in the Telega valley.

Methods of Production.—Roumania has been, *par excellence*, the country of the "dug pit," and it is the pioneer work done by the peasants and others in proving the shallow beds that has

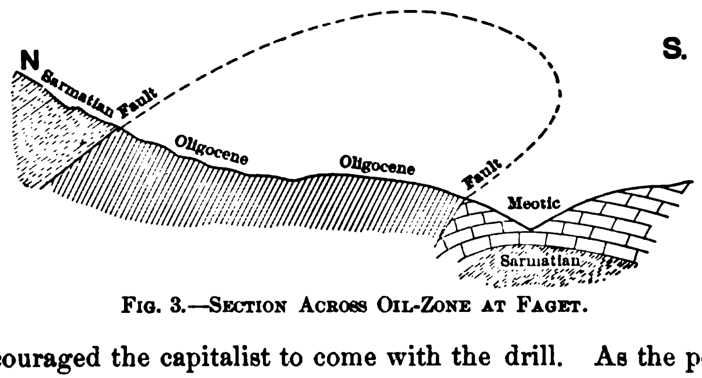

FIG. 3.—SECTION ACROSS OIL-ZONE AT FAGET.

encouraged the capitalist to come with the drill. As the peasants and smaller workers have been bought out, in order to drill for the deep oil, they have moved on to explore new lands.

These "hand-dugs" are surprisingly deep at times, attaining 750 ft. The cost of a hand-dug of 650 ft., with its lining of impermeable clay and wood-work, together with the requisite tanks, is given as 17,500 francs. These hand-dugs often give a steady, though small, yield for periods ranging up to 20

years. Flooding, "gassing" of the workers, explosions and quicksands are their chief obstacles. But good average hand-dugs will give a clear profit of 2,000 to 2,200 francs per annum, besides repaying their original cost.

Drilled Wells.—These are coming rapidly into vogue, but the deepest ones (*i.e.*, Campina, 2,600 ft.) have not been producers, the deepest producing wells being usually from 1,600 to 2,000, while the shallowest are only 130 ft. deep.

A good average well should yield about 30,000 kg. of petroleum per day.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

A Simple Rotary Distributor for Blast-Furnace Charges.

BY DAVID BAKER, PHILADELPHIA, PA.

(London Meeting, July, 1906.)

IN a paper presented to the American Institute of Mining Engineers, September, 1904, entitled "Improvements in the Mechanical Charging of the Modern Blast-Furnace,"[1] I showed the great fault of mechanical charging-devices to be that the materials charged by the dumping of the skip were separated, the coarse materials having high velocity, and the fine, low—thus giving paths of low resistance through the stock in the furnace, which resulted in unequal distribution of the furnace gases, unequal reduction, slips, scaffolds, irregular cutting of the inwall, "off" iron, and increased fuel-consumption. I showed how this could be prevented by rotary distribution, through which the irregular distribution in one layer charged is compensated by charging the subsequent layers from successively varied positions of the charger, and becomes practically eliminated when the angle between two successive positions is a little more or less than an even fraction of a full circle. Of all the devices then on the market, the nearest approach to the ideal arrangement was found in the Brown distributor, a full description of which was given. The one defect pointed out, however, was the difficulty of maintaining so much mechanism on the top of a blast-furnace.

Since the presentation of that paper, I have designed a very simple form of rotary distributor, which may be applied to any form of double-bell charger, retaining the perfect gas-seal, which is so admirably obtained by that construction.

In seeking protection for this invention, I found no similar distributor on record in the patent offices of the various countries where application was made; but an application show-

[1] *Trans.*, xxxv., 553.

ing the same construction was filed in the United States shortly afterwards by Mr. Albrecht B. Neumann, of Chicago, Ill. A joint ownership of the invention was the result; and the apparatus has received the name of the Baker and Neumann distributor.

Fig. 1 shows the top of a modern skip-filled furnace, provided with a main bell, closing the mouth of the furnace, and a gas-seal bell above, closing the gas-seal. It will be noticed that this small bell, which in ordinary construction permits a discharge of the materials all around its periphery, is here provided with a deflector plate that causes the material to discharge only around one-half of its circumference, when the bell is lowered. The dotted lines show the position of the distributing-bell and plate when the load is discharged.

Rotation is given to the bell and plate during its upward movement to close, by the ratchet lever (A) which drives the bevel gear (B) through which the hollow rod (C) passes, but to which it is rotatably connected by two wings or feathers, projecting from opposite sides of the hollow bell-hanger and traveling in corresponding grooves in the hub of the bevel gear (B).

Fig. 2 is an enlarged view of the upper end of the hollow distributing-bell hanger, the crosshead connection to the bell-operating beam and the bevel-gear driver, showing also the ratchet-lever (A) and its method of attachment to the bell-operating lever with the connection of the indicator-rod leading to the ground.

By drilling holes where required, the ratchet-lever may be provided with several points of attachment to the bell-beam, and the revolution of the distributor set at any angle desired. The ratchet permits the lowering of the distributing-bell without imparting any turning movement to the plate and bell; but during the closing of this bell, when it is without any load, the rotation is made.

This construction can, therefore, be made strong and simple, with few parts, requiring very little attention, and practically as simple and durable as the bell-beams. The preferred method of operation is to send the fuel of the charge to the top in four skips and the ore and limestone in the following four skips; but in some localities it has been found advantageous to hoist the flux and coke together.

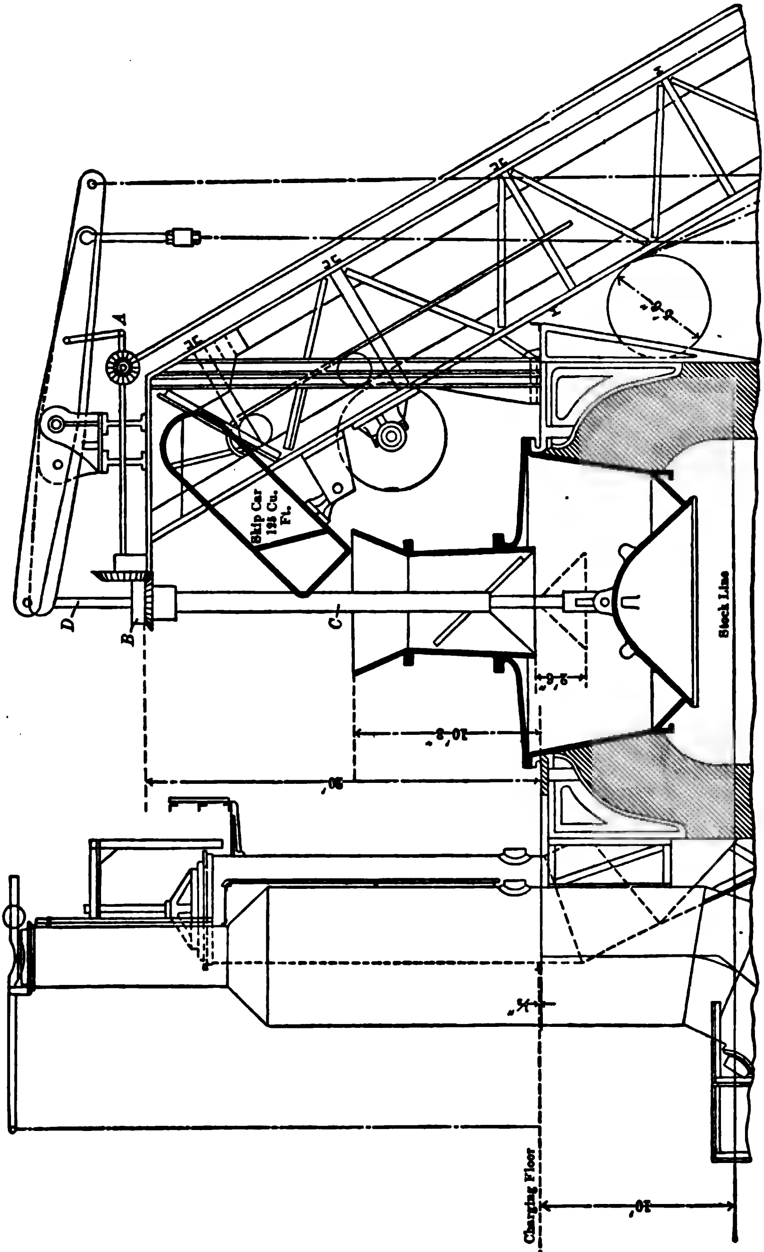

Fig. 1.—Top of a Modern Skip-Filled Furnace.

When the whole charge is thus hoisted in eight skips, the distributing-bell is set to rotate 91° at each discharge, which causes the center points of each discharge of the distributing-

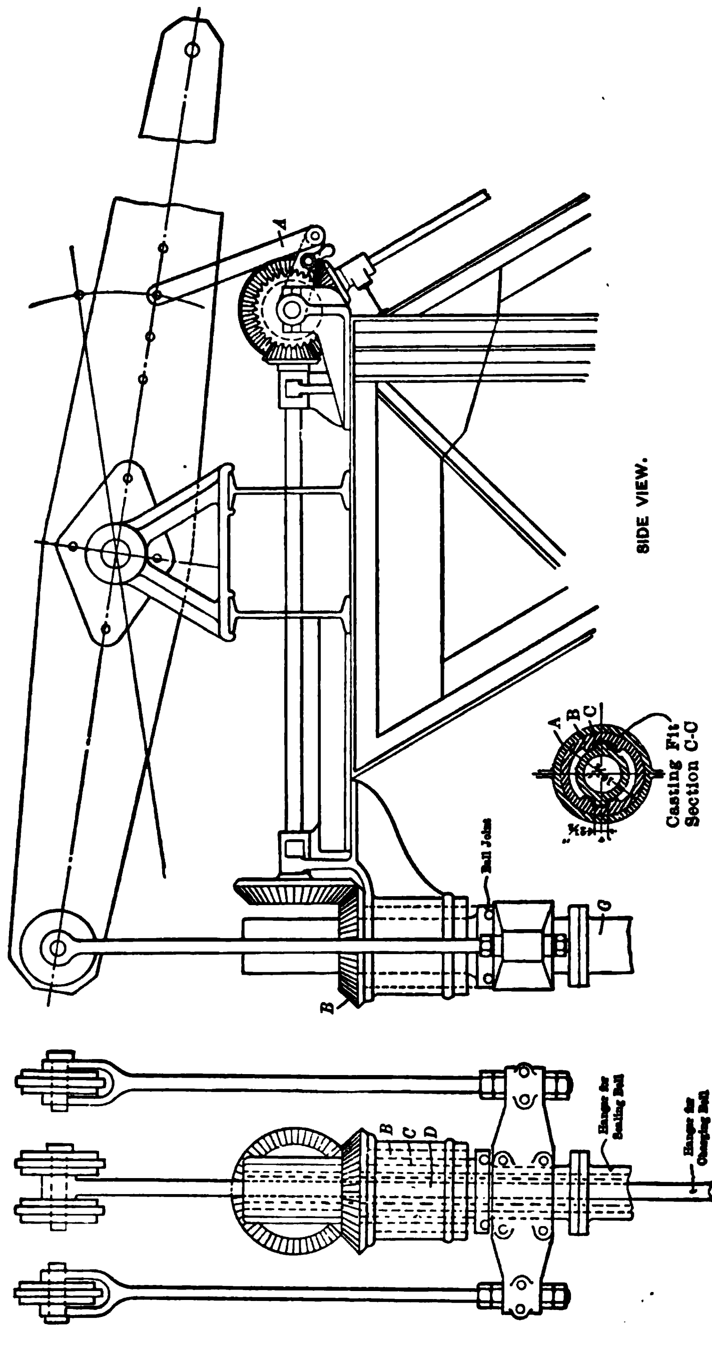

FIG. 2.—ENLARGED VIEW OF RATCHET LEVER.

bell to rotate 8° for each charge from the position of the preceding charge. The overlapping corrects the sorting which may have been made in any one charge.

It is possible, when desired, to arrange the throw of the distributor a little more than 120° or 180°, depending on how the furnace charge is to be hoisted, but I prefer to hoist the charge in eight skips and give a 91° movement to the distributor.

At the present writing, seven furnaces have been equipped with this device, the first one having been installed a little over a year ago. As was expected, the mechanical part of the arrangement has given no trouble whatever. A door is provided, however, in the receiving-hopper, through which, by means of a steel bar and sledge, the plate may be cut loose in a few minutes, and dropped into the furnace. Fortunately, this safeguard has never been needed.

The results of the operation of this method of distribution have been very gratifying. The work of the three furnaces in which the device was first installed, compared with their previous record, shows an average saving in fuel of 5.4 per cent., an increase in production of 21.6 per cent., a large reduction in the flue-dust thrown off, and a great increase in regularity of running.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Washoe Plant of the Anaconda Copper-Mining Co. in 1905,

BY L. S. AUSTIN, HOUGHTON, MICH.

(London Meeting, July, 1906.)

I. Introduction.

The Washoe plant,[1] in Anaconda, Mont., together with the local street-railroad, ranches, a foundry and machine-shop, a

[1] *Trans.*, xxxiv., 265.

brick-plant and the Montana hotel, form a property under one management; to which should be added the mines in Butte owned by the company, from which part of the ore-supply of the plant comes. The Anaconda Copper Mining Co., controlled by the Amalgamated Copper Co., was reorganized under the laws of Montana in 1893. A map of the plant, showing the numerous departments and illustrating the details of tracks, pipe-lines, and charging-stations for compressed-air locomotives, is given in Fig. 1.

II. Organization.

Apart from the general organization of the Anaconda Copper Mining Co., already mentioned, the plant and accessories are under charge of the local manager, Mr. E. P. Mathewson. This is the largest non-ferrous metallurgical plant in the world, and illustrates, under the given conditions, the natural development resulting from the necessity of a complex organization.

With many smaller metallurgical plants the organization has generally been arranged so that the business manager gives his whole attention to business details, while the superintendent attends to the technical matters. With the Anaconda Copper Mining Co., however, a technical man was chosen to attend to business details also; the wisdom of this arrangement has often shown itself, since, in this particular case, the mastery of business detail has been as satisfactory as when performed by one who had always confined his attention to business only. Moreover, a comprehensive view of the whole process by a master of technical detail has proved equally gratifying. For example, the 50-ft. reverberatory furnaces of three years ago were successively increased in length to 65, 85 and 102 ft., since it was not known what length of furnace could be used. To make these changes required the expenditure of $120,000 (all of which was recovered out of the economies attained during the course of the experimenting), and success required a complete knowledge of the technical side of the problem, as well as a clear idea of what the finances of the company would permit. Again, in increasing the length of the blast-furnaces at one time from 15 to 51 ft., it was necessary to know whether it were possible to remove a jacket while the blast was on, and to cut out or to repair one part of the furnace while the rest was in operation. At the time the change was made copper was

selling at a profitable figure, and it would not do to shut down in order to make changes. It was therefore necessary to make the change with practically no delay in running. With such considerations on the financial side, the manager knew he must advance only along lines involving no delay; had he to do with the technical side alone, he might have put up with the apparent necessity of shutting-down so as to make the improvement.

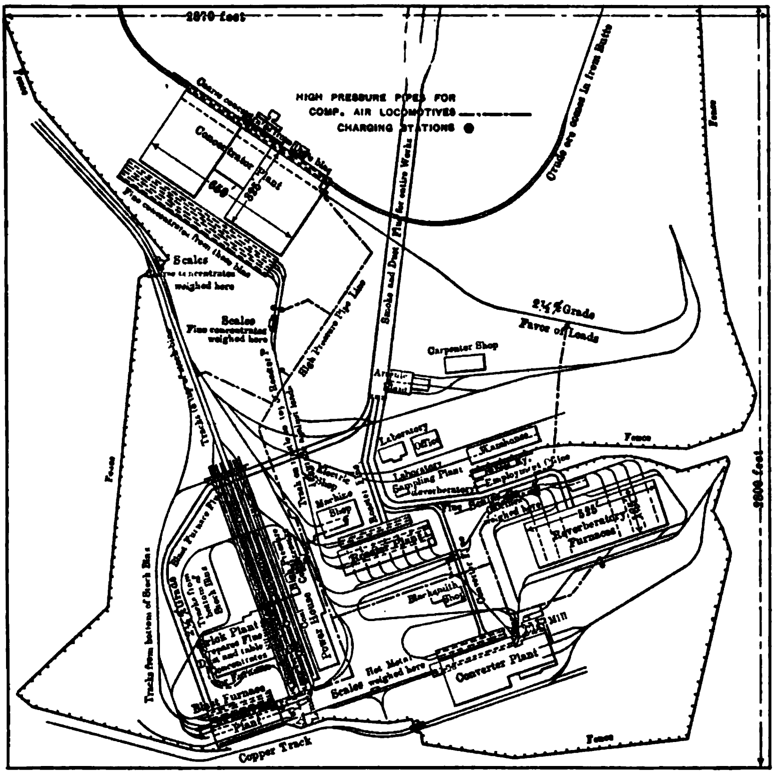

FIG. 1.—PLAN OF THE WASHOE PLANT OF THE ANACONDA COPPER-MINING CO., ANACONDA, MONT.

In order that the manager might give the closest attention to technical questions, an assistant superintendent was appointed to advise with him and with the heads of departments, and to take his place during his necessary absences.

The different departments about the works are under charge of foremen or superintendents, who are specialists in their lines of work, and who work in harmony with one another. There

are superintendents for the concentrating-mill, sampling-departments, power-houses, blast-furnaces, converters and the arsenic-plant; also chief foremen for the reverberatories, the roasters, the briquetting-plant and the slime-ponds. In addition, there is a general foreman of the works, who has full charge and authority in the absence of the superintendents of the departments. The 8-hr. system, in use at Anaconda, requires that there shall be three shifts daily, so that the general foreman is relieved by two foremen who assume his duties on the other shifts and who relieve each other on the afternoon and night-shifts every two weeks, while the general foreman always keeps the morning or day-shift. The departments having superintendents also have foremen, a head-foreman, holding the morning-shift, and two reliefs alternating on the other two shifts. The chief, or morning foreman, has the larger measure of authority and of responsibility. Thus, at no time is any department left uncontrolled, since the foremen relieve one another, and, as an additional precaution, the general foreman attends not only to the general supervision of the plant but also to those matters belonging to no particular department. Repairs and general construction are under supervision of the mechanical superintendent with an assistant and a head-mason. The complex handling of materials is in charge of a master of transportation. For experimental and control work there is an engineer of tests. A chief chemist reports all assays and determinations. The accounting is supervised by a chief clerk, and the purchasing of supplies, both for mine and works, is in charge of a purchasing agent.

III. PRODUCTION.

The various improvements in the Washoe plant have resulted in a largely increased production[2] in 1905 above that of the preceding year. In 1904 there was treated daily 5,500 tons of smelting- and concentrating-ore, yielding an output of 350,000 lb. copper. In 1905 the plant handled 7,000 tons of ore daily, the resultant output of copper being 500,000 lb. The following was the average monthly output in 1905:—Copper, 15,000,000 lb., @ 18.53c. per lb., $2,780,000; gold, $95,000; silver, $432,000; total, $3,307,000.

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[2] *Anaconda Standard*, December 25, 1905 (corrected).

The monthly pay-roll during 1905 amounted to $215,000. The average number of men employed in all departments at Anaconda was 2,450. The following data of daily operations may be of interest:—Ore treated, 7,000 tons; coal consumed, 600 tons; coke consumed, 400 tons; lime-rock used, 1,600 tons; flue-dust produced, 190 tons; slag and tailings produced, 9,000 tons; yield of copper, 500,000 lb.

IV. Transportation.[3]

About 11,700 tons of ores, limerock, coke and coal are brought in daily by railroad-cars, the switching being done on tracks of the Oregon Short-Line railroad. The ores and limerock come in 50-ton hopper-bottom cars, the coke in box-cars, and the coal in hopper-bottom or gondola cars. Deliveries of ores and limestone are made to bins or pockets, having outlet-chutes for drawing off the ore. Counting rehandled materials twice, more than 18,000 tons are handled about the works by means of 13 compressed-air locomotives, 12 weighing 13 tons each, and one, 21 tons. Each locomotive carries two storage-tanks for its air-supply, the air being taken from a pressure-system of pipes laid conveniently to the tracks, and having stations at which the locomotive stops to get its air-supply. This supply is carried at from 800 to 900 lb. per sq. in. A reducing-valve between the storage-tanks and the cylinder reduces the pressure to 150 lb. A fresh supply of air is taken at times ranging from 20 to 60 minutes. For this particular service, where the distances run are short, and where the cars are frequently stopped and started, the compressed-air locomotives have been most satisfactory, for convenience, reliability and simplicity of operation. They have been in constant service since 1900, and have needed only the natural running-repairs. They are operated over tracks aggregating 48 miles in length, which are distributed over the side-hill location of the works about half-a-mile square. Were electric locomotives used, the over-head trolley-system would be a most complicated one. Moreover, the present locomotives have been able to stand the hardest and roughest usage with but little injury. Under like conditions, one could be assured that electric locomotives would have had

[3] *Cassier's Magazine*, October, 1905, p. 466.

coils burned out, short-circuiting, and other troubles, apart from the danger arising from the wires themselves. The work must be done at all hours of the day and night, under the most varied weather conditions, and often surrounded by fumes of sulphur and dust. Endless spotting and shifting has to be done in order to weigh, load and unload the material handled. For example, in the case of the locomotive hauling the matte-ladles, they must be spotted for weighing three times on each round trip, in addition to three other stops, two for loading and unloading, and one to set the ladle on a side-track for cleaning. In the case of the 18-charge car-trains, each car of 2.5 tons capacity, the five ingredients of the charge must be weighed separately, and each two cars must be spotted to receive the ore from the chutes, and weighed for each ingredient. In charging, each train must be moved and set eight or ten times while unloading. If steam-locomotives had been used, the smoke and steam in the buildings and under the bins would have interfered seriously with the signalling to the engine-runner.

The pipe-system, which serves to supply air to the various stations for the use of the locomotives, is composed of pipes varying from 6-in. to 2-in. in size. Even at the high pressure of from 800 to 900 lb. per sq. in., it has developed practically no leaks. The air is furnished by two 4-stage air-compressors, having cross-compound steam-cylinders equipped with Corliss valve-gear. The compressors are equipped with automatic regulators to ensure constant high-pressure air.

V. Sampling.

The sampling-mill, furnished with a Brunton automatic sampling-machine, is used principally for sampling the concentrating and first-class or smelting-ore from the mines of the company and from others affiliated with the Amalgamated Copper Co.

Of the concentrating-ore, every fifth car is reserved for regular sampling, while all the smelting-ore is sampled, and the finer portion, under ⅜ in. in size, is screened out as first-class fines, to be made, together with other ingredients, into briquettes.

The mill adjoins a high-level track, by which ore is brought to discharge into hopper-bottomed steel-lined bins, from which

the mill supply is taken. Fig. 2 shows, diagrammatically, the course of the ore through the mill, and from it will be noticed that four cuts are taken out by four automatic sampling-machines; the ore being crushed finer after each cut, and before the new cut is taken out. In the figure, the rejected portion of the ore is represented as being delivered to a car upon the

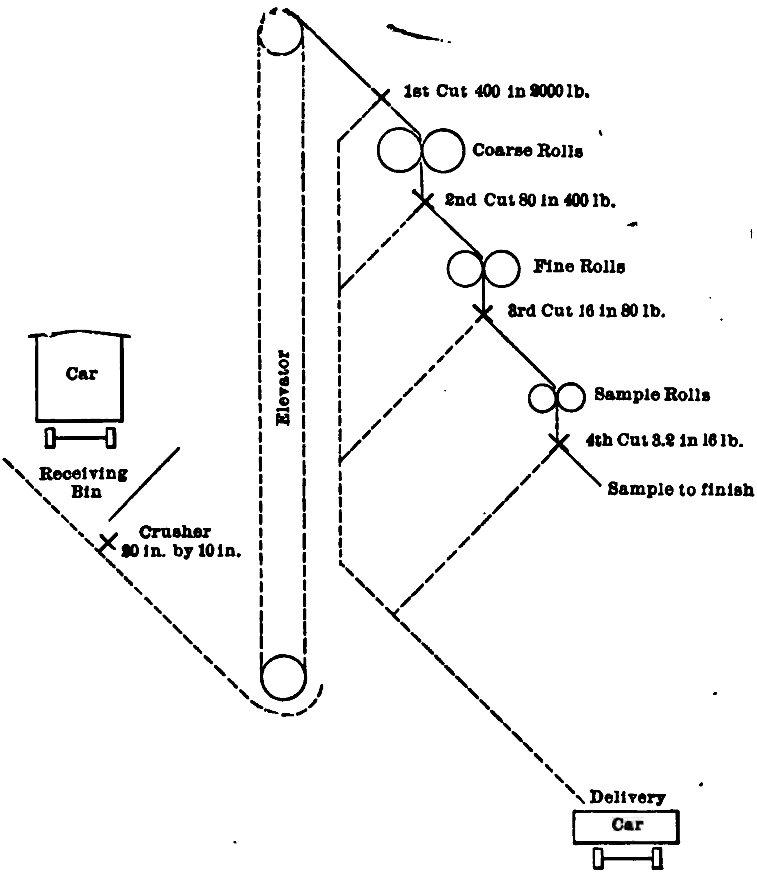

FIG. 2.—FLOW-SHEET AT AUTOMATIC SAMPLING MILL.

low-level track adjoining the mill. As a matter of fact, this portion is raised by elevator to trommels, in order to remove the fines. In consequence, a ton of 2,000 lb. is represented by 3.2 lb., or one 625th of the original portion taken. Thus, in a 500-ton lot there would remain 1,600 lb. of a sample. The portion so obtained is mixed in a pile and quartered down by means of a Brunton quartering-shovel. The reduced sam-

ple is ground through a sampling-grinder of the Leadville-Engelbach type, after which it is mixed, and further reduced by riffles. The grinding-plates, Fig. 3, upon which the pulp is ground to pass an 80- to 100-mesh screen, has three raised sides and rounded corners. The muller used in the sampling-room is shown in Fig. 4.

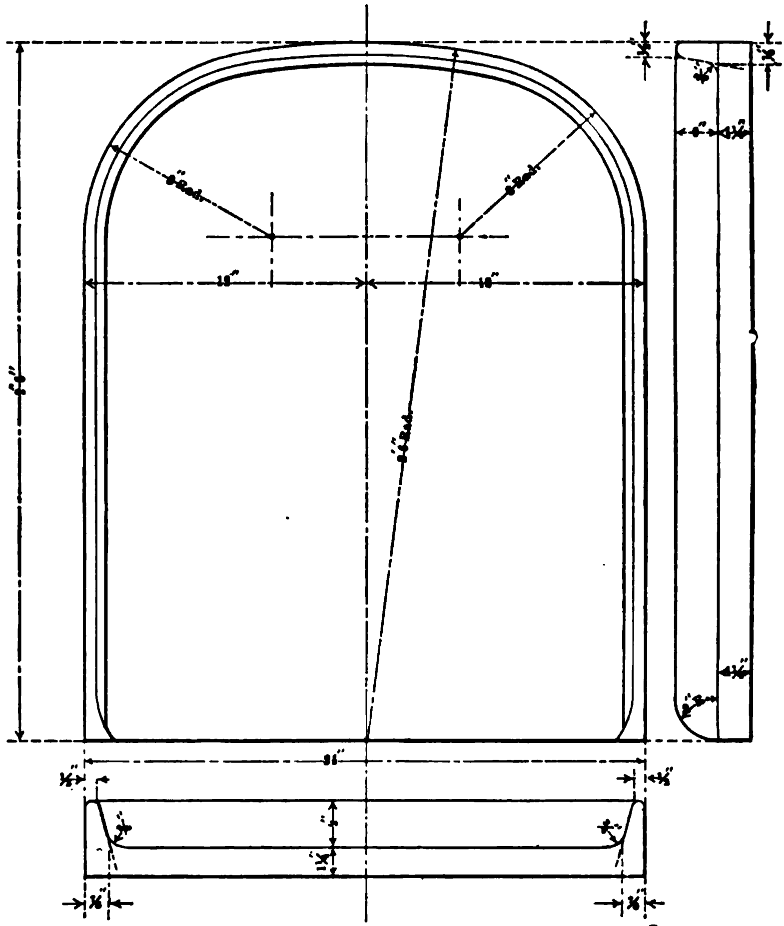

FIG. 3.—GRINDING-PLATE FOR FINISHING ORE-SAMPLES.

Samples of all metallurgical products about the works are handled at the laboratory sampling-plant—a sampling-mill situated centrally of the works. About 9,000 samples monthly are taken at different stages of operations, and include ore, concentrates, tailings, calcines, slag, matte, flue-dust, converter-

copper and anodes. A control of all the metallurgical work is thus obtained, and, when combined with the systematic weighing of all charges, ensures a complete control of the operations

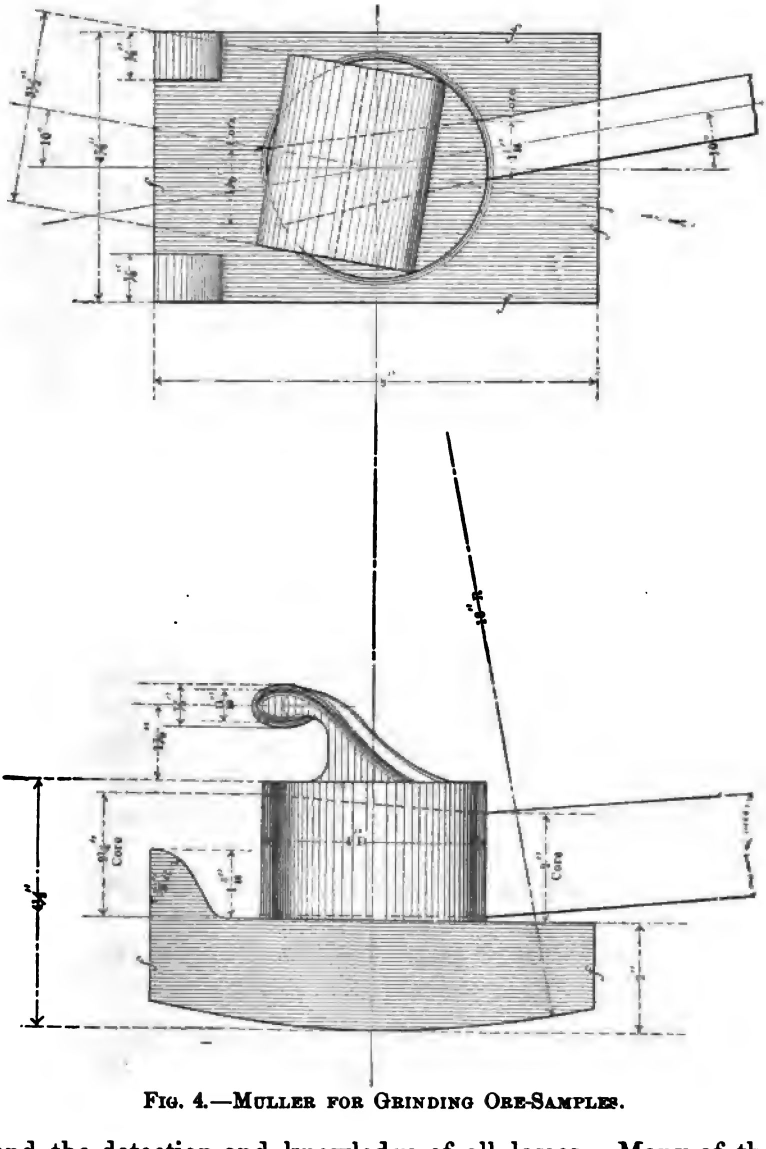

FIG. 4.—MULLER FOR GRINDING ORE-SAMPLES.

and the detection and knowledge of all losses. Many of the samples taken are small "grab" samples, as well as those taken systematically. Consequently, the machinery is simple, the grinding being done in sample-grinders and finished on buck-

ing-plates. The samples are dried out, either upon a steam-bath, 4 ft. by 12 ft. in area, or in a steam-closet, where they are placed in pans between racks of steam-coils. As fast as they are finished, the rejected portions of samples are sent to an elevated bin for eventual return to the works.

VI. CONCENTRATION.

The concentrating plant, elsewhere described by Mr. M. Schwerin,[4] has a side-hill or terrace location, and adjoins the high-level track and storage-bins, from which it draws its supply of ore. It consists of two mills, with a power-house between. Each mill has four sections, so there are eight in all. The capacity of a section may be given at 1,000 tons per day of 24 hr., and it may be estimated that 7.5 sections are constantly running, or that one section is down half of the time for repairs or adjustments. This would give a daily capacity, when the ore supply is sufficient, of 7,500 tons. A maximum output of 8,250 tons, however, has been attained. There is a large power- and boiler-plant between the two halves of the concentrator building, but much of this installation will be thrown out of use when the company obtains its power by electric installation from the plant of Georgetown Power Co., 22 miles distant, and the Missouri River Power Co., near Helena, 75 miles away.

To supply the eight units, already specified, there are 8 storage-bins, each of 1,200 tons capacity. These bins have flat bottoms, the ore forming its own slope in them, so that the wear of the bin is slight.

The following outline describes the flow of the ore through one section of the mill:—

(1) Hopper-bottomed cars of 50-ton capacity to (2).

(2) Storage- or supply-bin of 1,200 tons to (3).

(3) Shaking feed-trough, having a screen-bottom of 1.25 in. round holes, oversize to (4), undersize to (7).

(4) Coarse crusher, 12 in. by 24 in., to (5).

(5) Two trommels, each 36 in. in diameter by 5 ft. long, and having 1.25-in. round holes, oversize to (6), undersize to (7).

(6) Two crushers, each 5 by 15 in., to (7).

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[4] *Engineering and Mining Journal*, vol. lxxvi., p. 388 (Sept. 12, 1903).

(7) Two elevators, having 15-in. belt, buckets 7 by 14 in., speed per min. 450 in., to (8).

(8) Two trommels, 36 in. in diameter by 6 ft. long, and having ⅞-in. round holes, oversize to (9), undersize to (13).

(9) Two 2-compartment Hartz jigs on 1.25-in. feed, concentrates to (12), middlings to (16), through (15), (8) and (13), hutch product to (14).

(11) One coarse roll, 42 by 15 in., 1,147 ft. peripheral speed, to (13), through (8).

(12) Coarse-concentrates bin, concentrates to blast-furnace in hopper-bottom cars.

(13) Two 7-mm. trommels, 36 in. in diameter by 8 ft. long, oversize to (10), undersize to (16).

(14) Twelve 2-compartment Evans jigs on 7-mm. feed, size of screen 24 by 41 in., concentrates to (32), middlings to (35), hutch product to (32).

(15). One fine roll, 42 by 15 in., 1,147 peripheral speed, to (16), through (8) and (13).

(16) Four 5-mm. trommels, 36 in. in diameter by 6 ft. long, making 20 rev. per min., oversize to (14), undersize to (18).

(17) Twelve 2-compartment Evans jigs, 5-mm. feed, concentrates to (32), middlings to (35).

(18) Four 2.5-mm. trommels, 36 in. in diameter by 7.5 ft. long, oversize to (17), undersize to (19).

(19) Twelve 2.5-mm. Evans jigs, concentrates to (32), middlings to (35).

(20) One middlings-roll, 42 by 15 in., to (21).

(21) Four 1.5- by 12-mm. diagonal-slot trommels, 36 in. in diameter by 6 ft. long, oversize to (20), undersize to (22).

(22) Four 3-spigot separators, spigot-product to (23), overflow to (26).

(23) Eighteen 3-compartment middling-jigs, 1.5-mm. feed, concentrates to (32), middlings to (24), tailings to dump.

(24) Three 6-ft. Huntington mills, 53 rev. per min., 62-ton capacity, grinding to pass a 1- by 12-mm. slot-screen, to (25).

(25) Eighteen 3-compartment Huntington mill finishing-jigs, 1-mm. feed, concentrates to (32), middlings to (24), tailings to dump.

(26) Sixteen settling-tanks, 5 ft. wide by 4 ft. deep by 18 ft. long, spigot-product to (27), overflow to (28).

(27) Eighteen Wilfley tables, concentrates to (32), tailings to dump, slime to (29), middlings to (34).

(28) Slime-ponds situated below the reduction works.

(29) One large tank, spigot-product to one Wilfley table, (30), overflow to (28).

(30) One Wilfley table, concentrates to (32), tailings to dump.

(31) Elevator to (32).

(32) Settling-tanks, concentrates to roasting-furnaces, overflow to (28).

(33) Eighteen Wilfley tables, concentrates to (32), tailings to dump, slime to (28).

(34) Eight tanks, spigot-product to (33), slime to (28).

It will be noticed, in this scheme of separation, that no product of the coarse jigs is allowed to go to waste, but that all the portions, going over the tail-boards of these jigs, is recrushed and sized for further jigging. No tailings go to waste larger than 1.5 mm. Screening by trommels is carried as far as practicable, after which the spigot-products of classifiers are used on the fine jigs. Settling-tanks are used for unwatering, and for classifying the unwatered product. All fine concentrates from the fine jigs and from the Wilfley tables pass to an extended series of boxes in which the concentrates settle out, while the supernatant water slowly passes through the boxes, dropping most of its load, the settled product being drawn off at the bottom of the boxes through water-tight gates or valves. The final muddy water, however, is carried half a mile by launders to the slime-ponds, elsewhere described. The coarse concentrates go to a set of hopper-bottom bins, from which they are drawn off to cars, and carried to the storage-bins at the blast-furnaces.

The concentrating-ore is practically chalcocite, enargite and pyrite in a quartz and aluminous gangue.

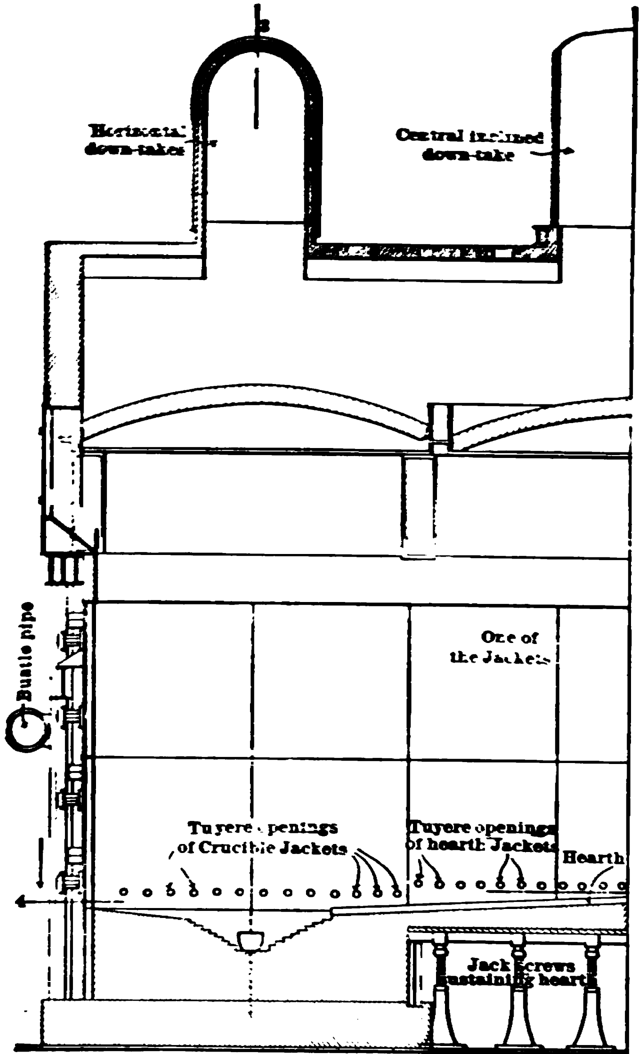
VII. Blast-Furnace Plant.

1. *Construction.*—The blast-furnace building formerly contained seven furnaces, each 56 by 180-in. area at the tuyeres. These were arranged with their longer axes parallel to the length of the building, for convenience of charging by means of track charge-cars. A new furnace was made by joining

furnaces Nos. 1 and 2 and including the 21-ft. space between them, which gave a furnace 51 ft. long, and of the original width of 56 in., as shown in Fig. 5. In a similar manner furnaces Nos. 3 and 4, and Nos. 5 and 6 were united; at present there are three large-sized furnaces, each 51 ft. long, and one furnace, 180 in., or 15 ft. long. At the slag-floor level are seven fore-hearths or settlers, as arranged for the original furnaces, which serve equally well for the enlarged furnaces, there being two fore-hearths for each. A matte-track, at a lower level, serves to bring in the matte-ladles, into which the matte of the fore-hearths is tapped. Fig. 6 illustrates a cross-section of the enlarged furnace, and Fig. 7 a cross-section of the building. Views of the interior of the blast-furnace from the levels of the feed-floor and hearth-level are given in Figs. 8 and 9. The large blast-furnaces, 56- by 612-in. tuyere-dimensions, have side-boshes of 8 in., making the width at the throat 6 ft. There is no end-bosh. There are two tiers of jackets, each 7 ft. 5. in. high. In either row, and on either side, the three central jackets are 7 ft. wide each, and the four remaining ones are 7 ft. 6 in. each, making thus the total length of 51 ft. The concrete foundation is surmounted by the two original crucibles, to which was added the connecting bridge, the latter formed of water-cooled plates supported by short jack-screws, as shown in Fig. 5. The crucibles, or sumps, as they may be aptly called, slope to the tap-hole. The bridge portion has a hearth sloping either way from the center to the crucibles. Thus the total drainage gravitates to either tap-hole. It may happen that the hearth becomes obstructed so as to throw more of the flow to one of the crucibles and less to the other. Such a result, however, need not interfere with the effective operation of the fore-hearths. Both crucible and hearth are made of silica brick, which has been found to be very enduring with the 40-per cent. silica slag here used.

Above the upper tier of jackets comes the heavy mantel-plate, 2 ft. 3 in. high, having a sloping front, and surmounted by the apron or receiving-plates, 21 in. high, with a slope of 45°, both together making a hopper upon which the charge slides down, tending to keep the finer charge closer to the walls, and the coarser material at the center of the furnace, all of which helps to promote regular working.

The furnace has a closed top, the fumes being carried off by three down-takes to the large dust-chamber adjoining the blast-furnace building. There are 46 tuyeres at the back, and 42 at

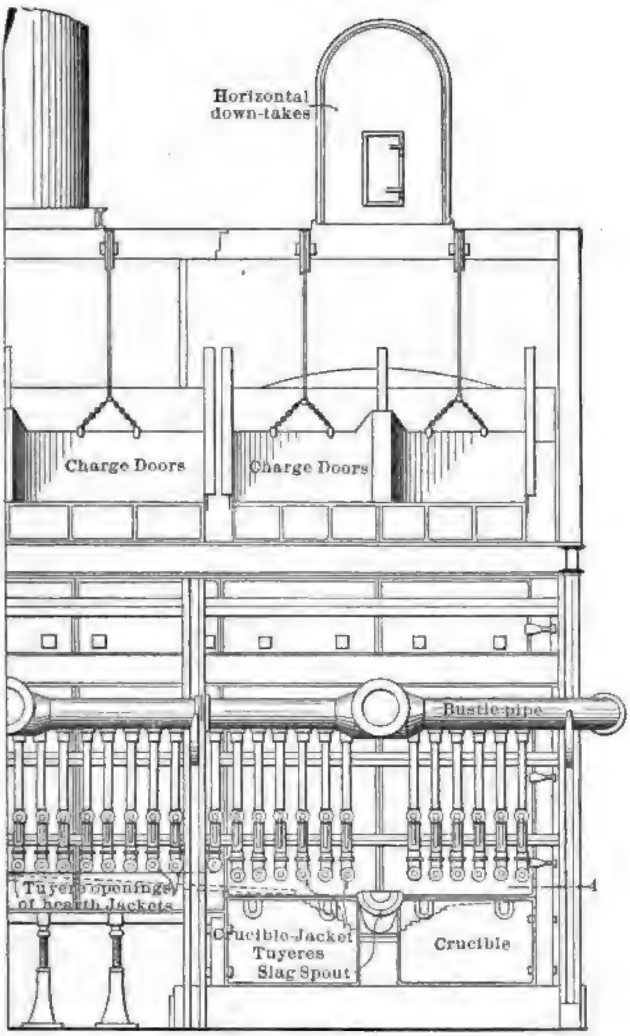


Half Longitudinal Sectional Elevation

FIG. 5.—SECTION AND ELEVATION OF

the front side of the furnace, or 88 in all, set at 14-in. centers. The space supplementing the lesser number of tuyeres at the front is utilized to make room for the two slag-spouts. It is customary to plug, or leave off, the four tuyeres nearest the

ends of the furnace, as this is found somewhat to prevent accretions, so that, practically, only 84 tuyeres are used. The omission of the the two tuyeres over the spouts does not appear to



Half Longitudinal Elevation.

THE 56- BY 612-IN. BLAST-FURNACE.

interfere with the proper operation of the furnace at this point, all of which indicates irregular working of tuyeres. Where it has been undertaken to cut out every other tuyere the furnace has not worked so well. This, indeed, may be due to the fact

that some of those tuyeres cut-out were in good working position, or, rather, that the more frequent tuyeres mean more

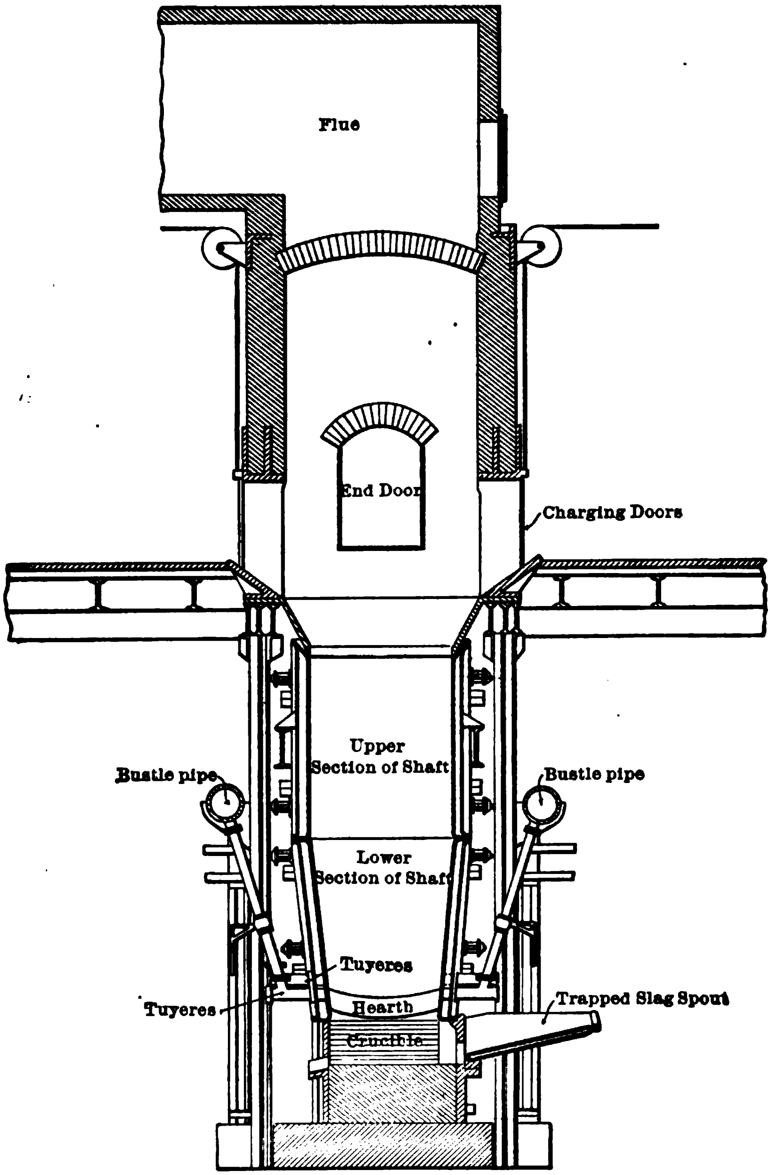


Fig. 6.—Transverse Sectional Elevation of 56- by 612-In. Blast-Furnace.

chances of getting air into the furnace. The tuyeres are punched several times on a shift, and it can hardly be sup-

posed that all the air enters the furnace by the small 1-in. hole thus formed. No doubt a good deal gets in between the jacket

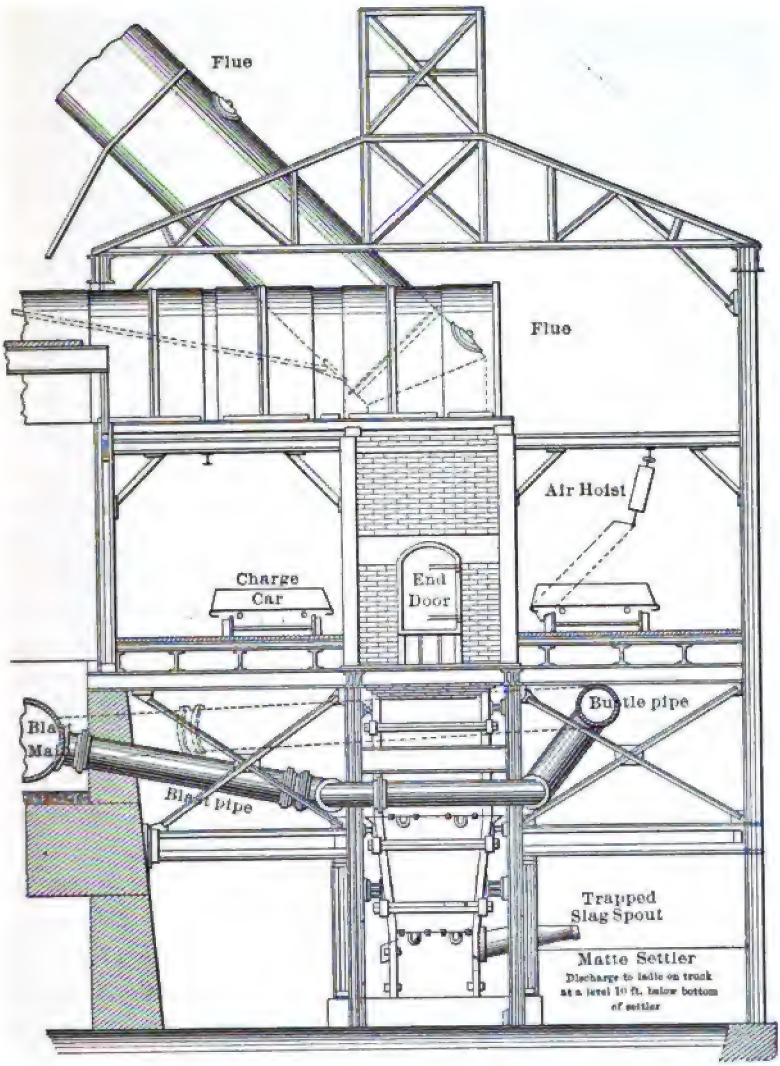


FIG. 7.—CROSS-SECTION OF FURNACE BUILDING AND THE ELEVATION OF 56- BY 612-IN. BLAST-FURNACE.

and the crust, eventually finding its way by devious passages (those of the least resistance) to the interior of the furnace.

The bustle-pipe extends completely around the furnace, with two branches from the blast-main, each with its own shut-off gate, so that, to shut down the furnace, two valves must be

closed. The tuyere pipes are 6-in. in diameter; the jacket opening being 4-in. in diameter, bolted to the jacket for easy removal in case of necessity. The connection to the blast-pipe is made by a galvanized iron sleeve, with a ring-clamp to make the joint tight. The fore-hearths or settlers, of the former smaller furnaces, serve equally well for the large ones. They are 16 ft. in diameter and 5 ft. high, the matte-tap being 3 ft. below the top of the fore-hearth. The slag enters on the side adjoining the furnace, and flows out on the opposite or front side. Experiments at Great Falls show the best point of outflow to be opposite the point of entrance. The discharging slag flows down a steeply-inclined spout, which delivers it opposite a 6-in., flattened water-jet situated just below the floor. This is supplied by jacket and other water. Besides this, there is a flow of water from the encircling cooling-pipe of the fore-hearth, which contributes to the stream that sweeps away the granulated slag through a semi-circular cast-iron lined launder, and conveys it to the dumping-point on the flats below the works.

The exterior of the furnace, having so long a side-wall, is braced and prevented from bulging by ties, carried around the furnace both at the level of the top of the lower jacket, and also under the floor. The horizontal pull of this bracing at the corner posts of the furnace is resisted by inclined ties attached to the floor above at adjoining corner posts, as shown on Fig. 7. It will be noticed that, between the three panels forming the length of the furnace, the jackets are supported by I-beams of the length of the panel (22 ft.). Two sets of the I-beams are to resist outward pressure of the jackets, the upper and heavier set to hold up the upper jackets when the lower ones have, for any reason, been removed. Two of the outlet or down-take flues (soon to be changed to resemble the central one) are of brick, and have hopper-bottoms for the removal of the flue-dust. The third, or central down-take, has an upward and then a downward slope, having a pitch so steep that no flue-dust can rest upon it. Flue-dust, on the upward-sloping flue, slides back to the furnace; on the downward-sloping side it goes to the dust-chamber.

The dust-chamber, 40 ft. wide and 280 ft. long, is provided with sheet-steel pyramidal hoppers, by which the flue-dust is conveniently drawn off to the charge-cars when they are run in

below. This chamber, 20 ft. high, affords a liberal space for the settling of the flue-dust. It is connected to the stack by

FIG. 8.—INTERIOR OF BLAST-FURNACE AT FEED-FLOOR LEVEL.

means of a flue of 20 ft. by 15 ft., or 300 sq. ft. area of cross-section.

2. *Operation.*—The furnace is charged through seven doors on each of the long sides, giving access to the entire length.

FIG. 9.—INTERIOR OF BLAST FURNACE AT HEARTH-LEVEL.

It also has end doors for barring out. The charge is brought in by a train of 18 cars at a time, each car holding 2.5 tons. Eight of these cars constitute a charge amounting to from 18

to 20 tons. The coke is charged separately in 2-wheeled buggies, each of 30 cu. ft. capacity, and capable of holding 900 lb. The amount used is 10 per cent. of the charge.

The weighing of charges to an 18-car train is thus performed:—The cars are spotted to the coarse-concentrates bins, where the specified quantity is weighed in (to two at a time), the flow being controlled by a slide-gate operated by hand. A swinging chute, operated by a compressed-air cylinder, also assists in controlling the discharge. After the concentrates, the 18 cars are simultaneously charged with the briquettes, as more fully mentioned in the description of the briquetting-plant. The train is then taken to the first-class ore-bins for the next item of the charge, then to the slag-bins, and the limestone-bins. It will be seen that, in this way of putting in the materials, the finer portion is at the bottom of the car, and it is so charged into the furnace that it falls to the near side, while the coarser material goes to the center portion of the furnace.

The temperature of the gases from all the furnaces, in the flue just beyond the dust-chamber, drops as much as 62° C., and the draft-pressure drops 0.2 in. of water when six of the 46 doors are open. The air, with a draft-pressure of 1.7 in. in the flue, has a velocity of 1.5 ft. per sec. through the doors (each of 20 sq. ft. area), and, with six doors open, an admission of 10,800 cu. ft. per min., or one-fifth of the total out-going gases. The quantity entering is proportional directly to the number of doors opened. Of the total heat developed by the burning of the coke and sulphur, 18.6 per cent. escapes in the outgoing gases, which, at the entrance to the down-take, have a temperature of 380° C. Not more than these six doors need be opened at any one time, either for charging or for cutting accretions or crusts from the furnace.

With regard to the influence of limestone, comprising approximately one-third of the charge, whose decomposition into CaO and CO_2, completed at 800° C., abstracts heat at the surface of the charge, and thus lessens over-fire: such decomposition takes 425 pound-calories per pound of limestone, or, as 3.5 lb. limestone is used per pound of coke consumed, it absorbs 1,487 calories out of the total of 6,680 calories developed by the combustion of this pound of coke and the 1 lb. of sulphur, which is disposed of at the same time.

On the other hand, at the zone of fusion, the CaO, in forming a silicate, evolves 297 calories, where such an evolution is most to be desired, resulting in an outflowing slag, which reaches a temperature of 1,150° C.

The temperature of the escaping-gases varies from 100° C., in a freshly-charged furnace, to 560° just before a new charge is put in, especially when there has been a longer interval than usual before again charging. These variations become greater as the jackets become more crusted over, such accretions forming to the thickness of several inches.

The addition of a fresh charge results in a drop of temperature of 200° C., while the opening of the doors on one side cools the gases 80° C., the difference, 120°, being due to the putting in of the cold charge. There results a gradual rise of temperature of 25° C. per min., the rise being retarded because of the endothermic action of the limestone, the evaporation of the water, and the heat absorbed in heating up the charge.

It would be well to note here, that, with a fusible self-fluxing charge containing but little limestone, and with so high a percentage of coke, this rise of temperature would be more rapid, and overfire would increase to such a degree, indeed, as to promote the greater formation of accretions which tend to crust over the top of the charge and to delay, if not stop, smelting.

With regard to the charging operation, I am not at liberty to give the proportions or analyses of the constituents of the charge at the Washoe plant, but, in Table I., I present a typical Montana blast-furnace charge made up from data in Prof. Hofman's paper, Notes on the Metallurgy of Copper in Montana.[5] The analyses of matte and slag are from the same source, and from Peters' book on Copper-Smelting (7th ed., p. 552). Compared with the charge calculation given by him on p. 367, there is but little flue-dust made. To-day, all fine concentrates are sent to the roasters and then to the reverberatory furnaces. The fine ore is also screened out from the first-class ore and is worked into briquettes. Thus the flue-dust loss has been cut from 18.75 per cent., which he mentions, down to 3 per cent. in present practice. The grade of the matte has also been re-

[5] *Trans.*, xxxiv., 258.

TABLE I.—*Charge Sheet.*

Name of Ore.	Moisture.	Weight.		Cu.		SiO_2.		Fe and Mn.		CaO and MgO.		S.	
		Wet.	Dry.	Per Ct.	Wt.	Per Ct.	Wt.	Per Ct.	Wt.	Per Ct.	Wt.	Per Ct.	Wt.
Coarse concentrates	8.0	1,550	1,500	8.7	130	22.0	330	27.0	405	......	....	35.7	535
Briquettes	8.0	1,620	1,500	6.9	104	45.0	675	11.0	165	......	....	17.0	255
First class ore	8.0	2,060	2,000	8.0	160	50.0	1,000	12.1	242	0.5	10	15.4	308
Converter-slag	......	1,500	1,500	2.0	30	30.0	450	42.9	643	1.0	15	0.7	10
Limestone	......	3,500	3,500	......	......	5.0	175	1.0	35	51.0	1,785	......	....
Coke	......	....	1,020	......	......	6.9	70	1.2	12	0.8	8	0.7	7
		10,230			424		2,700		1,502		1,818		1,115

Weight of slag, $\frac{2,700}{40 \text{ per cent.}}$ = 6,750 lb., or 67 per cent. of charge.

Cu in slag, 6,750 by 0.33 per cent. = 22 lb., or Cu_2O = 25 lb.

Cu in matte, 424 — 22 = 402 lb., and the matte weighs $\frac{402}{40 \text{ per cent.}}$ = 1,005.

Fe in matte, 1,005 by 30 per cent. = 301 lb., leaving for the slag 1,502 — 301 = 1,201 lb., or of FeO 1,544 lb.

S in matte, 1,005 by 23 per cent. = 231 lb., and in slag 26 lb., or in both 257 lb.

S volatilized 1,115 — 257 = 859 lb., or 77 per cent. of the total sulphur.

From these data we have in the slag SiO_2 2,700 lb. (40 per cent.); FeO, 1,526 lb. (22.5 per cent.); lead, 1,818 lb. (26.9 per cent.); Cu_2O, 25 lb. (0.4 per cent.); S, 26 lb. (0.4 per cent.); other bases, by difference, 9.8 per cent.

From Peters[6] we have taken a matte, and used it in our calculation, of the composition, S, 23 per cent. (231 lb.); Cu, 40 per cent. (402 lb.); Fe, 30 per cent. (301 lb.); other bases, 7 per cent. (71 lb.).

The matte-fall, based upon the entire charge of 10,230 lb., is 10 per cent., and the concentration, 5 tons of ore into one of 40-per cent. matte.

duced from 50 per cent., the practice at the time the book was written, to 40 per cent., as now made. It is now possible to work 40-per cent. copper-matte successfully in the converter, because of the firmer quality of the lining due to the power-rammers used. The loss by volatilization, 80 per cent. of sulphur, has, in spite of the large amount present, resulted in giving a 40-per cent. matte. This has been brought about, in part, by the use of a high-pressure blast of 40 oz. per sq. in., which shows itself in much over-fire and by the violent agitation of the materials at the surface of the charge.

The high pressure of 40 oz. is necessary because of the small openings by which the air enters the furnace, consisting of holes no more than 1 in. in diameter, where the slag has been pierced by the punching-bar, and of accidental seams between the jacket and its adherent crust, as well as by cracks and

[6] *Modern American Methods of Copper Smelting*, by E. D. Peters, Jr., 7th ed. (1895), p. 552.

seams in this crust. The estimate allows for no leakages about the tuyeres, and the continual sound of the escaping air indicates there is some loss from this source, a defect due to faults of construction, since, with the much higher pressures carried by the iron blast-furnace, the furnace-room is comparatively quiet. It may also be concluded that, with a more unrestrained entrance for the air, the pressure might well drop to half its present value, and that, moreover, with twice the volume of air now entering the furnace, twice the tonnage could be put through. It is true, in the case of these large furnaces, that improvement has been incompletely met in other details. The same feeble methods are used to-day in punching the tuyeres and in barring-down the large furnaces, that have been used for many years. Improvement in the delivery of air at the tuyeres is the direction in which improvement will best be repaid. It would result in a furnace needing a low smelting-column, in the dropping of pressure and, with it, the saving of power, as well as the ability of the furnace to increase its tonnage with the increase of the column of air admitted.

Crusts or accretions are to-day removed by attack from the feed-floor level by a gang of three or four men, who, exposed to the high radiant heat and fumes at that point, feebly work a heavy bar to break-down these accretions. I believe, however, that metallurgists are well aware of these defects, and at this particular plant they will endeavor to remove them, as soon as they can get to it. It must be remembered that the first of those 51-ft. furnaces has been in operation only since March, 1904, less than a year before the present writing. There seems now, however, but little chance of the solution of the problem of improved air-supply into the furnace when one takes into consideration the difficulties of the problem.

As indicated in Fig. 7, there is a track at a level 10 ft. below the slag-floor: The matte-ladles are run in and spotted to the desired furnace, and the fore-hearth tapped to the ladle. A dolly, having a 6-in. button-head, carries the conical clay stopper, made of a local clay. A full ladle of matte of 10 tons is drawn off. The flow is stopped with the dolly, the tapper pressing it in with all his force, while an assistant strikes the head of the dolly. The opening having been stopped, the tapping-bar is gently driven through the fresh clay, remaining

there until the next tapping. The launder, leading the matte to the ladle, is 12 in. wide, with a semicircular bottom lined with clay. There is a Y-branch launder to the other settler also, so that it is possible to tap from both fore-hearths to the same ladle. The ladle, when spotted, is ventilated by a hood suspended above it, which, terminating in a straight stack through the roof above, carries off the fumes.

It has sometimes happened, as after a shut-down, that the contents of the fore-hearth have become cooled. Directly after tapping the matte, and before the settler has again filled with slag, it has been warmed by blowing compressed-air into the settler, so as to bessemerize the molten matte still remaining in the settler. The reaction, being exothermic, serves to raise the temperature of the molten contents.

VIII. Advantages of Large Furnaces.

Numerous advantages, in the operation of the larger furnaces over the ordinary ones, show themselves upon study.

1. *Saving in Fuel.*—The large furnaces will work with 10 per cent. of coke where 11 per cent. has been needed for the 15-ft. ones. This arises from the fact that, while the sectional area at the tuyeres has increased 3.4 times, the radiating surfaces at the sides up to the top-surface of the charge (10 ft.) has increased but 2.4 times. Taking into account the lessened percentage of fuel, still 6 per cent. more is burned in unit time, thus increasing the maximum temperature and giving more satisfactory fusion. Mr. Mathewson, the local manager, thinks that in lead-smelting it should be possible to save 2 per cent. out of the 14 per cent. generally used.

2. *Saving in Jacket-Water.*—While the jacketed surface has been increased 2.4 times, the capacity has increased 3.8 times.

3. *Quick and Large Discharge of Matte and Slag.*—It will be noticed that the crucible is contracted in volume as compared with other practice on smaller furnaces. As a result, the contents of the crucible are more quickly discharged. The increased tonnage smelted gives an increased flow, so that there is less chance of obstructions forming, or, if formed, they are swept away in the large volume of slag and low-grade corrosive matte. The increased intensity of combustion, already alluded to, results in a hotter slag (1,170° C.); so markedly true is this,

that the 40-per cent. silica slag, usually carried, appears perfectly fluid, flowing with as much ease as I have seen with the 35-per cent. silica slags of ordinary practice. The high silica shows itself, however, upon withdrawing from the flow with an iron rod a portion which strings out in a characteristic manner. Indeed, it seems to me that the assigned limit of 40 per cent. might be far exceeded, were it not probable that tonnage would be reduced, because of the slower driving of the more siliceous slags. Whether in order to save limestone, or rather to increase capacity by its omission, slags of 60 per cent. or more will ever be found profitable, as in Mansfeld practice, is an interesting question. The temperature of the slag leaving has dropped, on an average, 50° C. The temperature of the matte remains much the same as when it enters. Thus we have temperature of entering slag and matte, 1,170°; of the slag leaving the settler, 1,120°; and the outflowing matte, when tapped to the ladles, 1,170°, and sometimes a little higher, indicating possible exothermic reaction going on within the forehearth.

4. *Decrease of Incrustation.*—Comparing the two sizes of furnace, the larger one may be considered as made by the union of three, placed end to end, a construction which was carried out by keeping the two adjoining furnaces running, while the intermediate portion was being built. At the last moment, and during a short shut-down, the dividing-walls were removed and the whole thrown into one. Thus we may reckon that four end-walls, out of the six needed in the three smaller furnaces, have been saved. This has by so much lessened the surfaces for incrustation, especially since it is at the ends of the furnace that the most trouble of this kind occurs. In fact, on the long side-walls accretions have little support, and it is necessary only to let the charge down, when the side-accretions will fall forward into the furnace. Bridging, however, may sometimes take place, thus holding-up the side-crusts. In such a case the bridge is smelted away, care being taken that when it goes, so much does not fall forward as to obstruct the furnace-operations at that point. With the heavy blast-pressure carried, 40 oz., the surface of the charge is in intense agitation, accompanied, just before charging, with much overfire and the projection of pieces of coke and materials of the charge. Hence

the importance of screening, in the case of all the first-class ore used, which, at the time of sampling, is passed over a trommel having ⅜-in. holes, the undersize going to the briquetting-plant. About 3 per cent. of flue-dust is caught in the dust-chambers, while a good deal of the projected material falls back into the furnace. The closed top promotes this action, since it gives a place for dust to settle. The charge-doors, when opened, also have a cooling and settling effect. The flue-dust caught in the chamber is sent to the reverberatories..

5. *Elasticity of Operation.*—As a preliminary to the operation of a large furnace, it was necessary to find out if it could be kept running while part of it was undergoing cleaning out or repair. To this end a jacket was removed while the blast-pressure was kept on and the furnace was continuing in operation. The crust, coating the jacket at that point, served to hold back the heat, so that while it was 7.5 ft. wide by 7 ft. high, it could yet be removed. This operation was much assisted by means of a compressed-air crab, both in pulling out the old and in hoisting the new jacket into place. On account of the demand for continuous operation, it was necessary to wait two or three months before a jacket had to be removed because of a leak. It was also found that, by removing adjoining tuyeres and the proper jacket, the dead portion of a hearth obstruction could be got at without serious trouble to the men. Where the heat showed too fiercely, a sheet of iron supported by bars served to protect the spot. The dead material having been removed from the crucible, the jacket was again put up, and this portion of the furnace again put into operation. Of course, all this diminishes the effective smelting-area, but it would cut proportionally less figure in a long than in a short furnace. It may be said, therefore, on account of the possibility of making repairs, and of cutting out while the furnace is still smelting, that campaigns may be considered endless, being terminated only if the supply of ore becomes exhausted.

6. *Large Flow Through Fore-Hearths.*—The capacity of the large furnace is 3.8 times as great as the smaller one; hence, nearly twice as much of the mixed matte and slag enters the fore-hearth in a given time. Despite the increased flow, an improved settling and a cleaner slag has resulted, due to its greater fluidity. The increased flow has also tended to keep

the fore-hearth hotter. Indeed, it was found profitable to give up the older 14-ft. settlers and to replace them by 16-ft. ones, because of the greater corrosion of the smaller fore-hearth by the matte. No more labor is needed because of the doubled flow. Certainly, the matte has to be tapped more frequently, but the same men can accomplish that also, since they have only 15 tappings to make in 24 hours. The slag, being granulated, takes no more labor, though more water is needed for granulating it. A fore-hearth or slag-spout is changed by stopping the flow at that tap-hole during the time. The united flow, therefore, goes through the other fore-hearth, which is able to perform the duty of both.

7. *Alteration Without Interruption.*—At the Washoe plant, as already mentioned, the longitudinal axes of the furnaces are parallel to the length of the building, a disposition suited to charging by charge-cars in trains. In consequence, it was possible to put in the bridge, jackets, top and down-take of the 21-ft. connecting portion. The end-jackets of the original furnaces were then removed, the crusts broken away, and the entire furnace brought into operation with practically no delay, at a time when output was all-important.

8. *Variations in the Composition of Slag.*—The part of the hearth most exposed to corrosion is the central, bridged portion. To lessen this action, the charge for that part of the furnace may be made more siliceous than normal, the ends less so; thus the average silica of the slag would be unaffected. Again, were it desired to put in a basic charge at one end of the furnace in order to smelt out a crust, this could be done without in any way affecting the other end of the furnace. In fact, it would be possible to run three different slags at the same time.

9. *Less Labor-Cost.*—As just shown, the cost for tappers and furnace-tenders at the slag-floor level is less; and, at the charge-floor, where power-feeding is used, the resultant cost for feeders is less also. On the other hand, the labor per ton for bringing in coke is not lessened. The present way of handling the coke is the cheapest and most practical, however, since the coke is taken direct from the cars in which it comes to the works, and is handled with less breakage than by any other system. In the practice of the Washoe plant the surface of the charge is

carried 6 ft. below the charging-door, giving a 10-ft. smelting-column, so that there is, undoubtedly, some breakage in dumping the coke direct from the coke-buggies into the furnace. It may be said, however, in defence of the practice, that it is followed because it is found that, when the charge is shot in from the charge-cart from that height, some segregation occurs, resulting in the finer ore going to the side and the coarser to the middle line of the furnace, as it should do. The labor for the original seven 15-ft. furnaces may be given as follows per shift of 8 hours:—

Upper floor:			
7 feeders,	@	$4.00	$28.00
8 coke-wheelers,	@	3.00	24.00
2 charge-loaders,	@	3.00	6.00
4 bin-men,	@	3.00	12.00
1 extra man,	@	3.00	3.00
Lower floor:			
1 foreman,	@	5.00	5.00
1 head-tapper,	@	4.00	4.00
7 tappers,	@	4.00	28.00
10 tapper-helpers,	@	3.00	30.00
1 flume watchman,	@	3.00	3.00
			$143.00

Or, for three shifts, $429 for an output of 2,940 tons. To this may be added 11 per cent. of coke @ $8.50 per ton, or $2,748.90, making a total for fuel and labor of $1.08 per ton. On the other hand, operating the three large (51-ft.) and one small (15-ft.) furnace, for labor per shift is obtained:—

Upper floor:			
4 feeders,	@	$4.00	$16.00
4 feeder-helpers,	@	3.00	12.00
13 coke-wheelers,	@	3.00	39.00
2 charge-loaders,	@	3.00	6.00
4 bin-men,	@	3.00	12.00
1 extra man,	@	3.00	3.00
Lower floor:			
1 foreman,	@	5.00	5.00
1 head-tapper,	@	4.00	4.00
7 tappers,	@	4.00	28.00
10 tapper-helpers,	@	3.00	30.00
1 flume watchman,	@	3.00	3.00
			$158.00

Or, for three shifts, $474 for an output of 5,220 tons. The coke

consumed, 10 per cent., at $8.50 per ton, costs $4,337, making the total for fuel and labor $0.94 per ton. This is a saving of 13 per cent. upon those two items, being $678.60 per day.

10. *Less Initial Cost.*—The cost of a large furnace with 3.8 times the capacity would not exceed from 2.5 to 3 times the smaller one. There are two fore-hearths and three down-takes for the 51-ft. furnace. The bracing of the long sides, in this particular instance, has been accompanied with but little additional expense, taking advantage of the trussing and the construction already existing. The same building serves to shelter the larger furnaces as effectually as it did the smaller ones, that is to say, the same structure is enough for an additional output of 2,280 tons, or 77 per cent. more than the original capacity.

IX. Briquetting Plant.

The building formerly contained two Chisholm-Boyd and two White briquetting-presses of a capacity of 125 tons each in 24 hr. To operate one machine and to handle and dry the briquettes, there were needed 8 men per shift, including the foreman, or 24 men daily. The briquettes were dried in an adjoining shed.

At present, the company has four end-cut, auger brick-machines, one being constantly in use, and having, for the single machine, a capacity of 840 tons of briquettes per 24 hours.

The briquettes are composed of one third ore (screened from the first-class ore), one third slimes from the slime-ponds of the works, the balance of so-called table-concentrates (the product of settling-tanks at the concentrator), and 5 per cent. of washed reverberatory coke. The washed coke is made from the ash-pit droppings of the reverberatories. It is conveyed from the ash-pit, in a stream of water, to the coke-washing plant, where the ashes and clinkers are jigged out, and a tailings of coke, of about chestnut size, is recovered. This material, worked into the brick, tends to give them an open texture, favoring the escape of the moisture quietly rather than explosively, as would be the case were the structure dense. The coke, thus incorporated, can be figured upon as replacing 40 tons daily of the more expensive oven-coke at the blast furnace.

These materials are drawn from inclined-bottom storage-bins to a conveyor-belt passing in front of the four hopper-chutes.

A man stands at each of three of the chutes to regulate their discharge, while the discharge of the coke-bin is regulated from a distance by the pug-mill man, who is standing at the pug-mill. The three men at the chutes become quite expert at sending along the proportion assigned to them, and their work is controlled by the pug-mill man, who also signals when they are to stop feeding.

The conveyor-belt discharges to another at right angles to it, which conveys the mixture to the supply-chute of the pug-mill, which is a double-spindle, horizontal mill making 22 revs. per min., in which the various ingredients are mixed with just enough water for molding in a brick-press situated below. The latter is a No. 7 end-cut, worm-feed brick-machine, made by Chamber's Bros. Co., Philadelphia, Pa. When first put in operation, from 400 to 500 tons were produced in 24 hr., but, with greater skill and better regulation, the output has been raised to a daily average of 840 tons, or to a maximum of 880 tons. To operate the plant there are needed 9 men per shift, including the foreman. The bricks weigh from 5 to 10 lb. each, and the machine, in full operation, can produce 160 bricks per minute. The bricks are again conveyed by a 10-in. flat rubber belt, to another, parallel to the long side of the building and commanding a set of hoppers placed directly over the center of a track, which is inside the building and is heated by steam. There are 36 of these hoppers, each capable of holding a ton of briquettes. Deflecting-boards sweep the briquettes into the hoppers, the man in attendance operating the deflectors so as to fill first the even-numbered, and then the odd-numbered hoppers. The hoppers are each 2 ft. 6 in. wide at the top, 2 ft. wide at the bottom, 3 ft. 4 in. long and 2 ft. 6 in. deep. They are steel-lined and have drop bottoms. The bottoms can be dropped simultaneously, or individually, as shown in Fig. 10. In this illustration the contents of two hoppers only have been dropped. In winter the room is heated by steam so that the briquettes will not freeze. Each alternate hopper is painted red, the others white; corresponding red and white lights indicate which set is full. When the hoppers are empty, no light shows.

A train of from 16 to 18 charge-cars is loaded as follows: about 200 lb. of coarse concentrates is drawn off to the cars from the

coarse-concentrate bins. The train is then spotted under the hoppers as indicated by the lights to take the charge of briquettes, and the bottoms of the proper bins are dropped together, thus filling the cars with one movement of a lever. The coarse concentrates are put into the cars first, in order to prevent the briquettes, which are fresh from the press, from sticking to the bottom. Where it is desired to omit the briquettes from any desired car, that particular lever can be thrown out of gear. The hoppers are so spaced that the alternate ones come over the centers of the charge-cars. The work goes on with great precision, and 18 cars, if desired, can be filled with a single movement of the lever.

It is to be noticed that these briquettes are not handled at all. They are used moist, not being dried. They crumble somewhat, but still stand handling well enough for smelting.

X. Roasting Plant.

1. *Kilns.*—The roaster building contains 56 McDougall roasters, as improved by Evans and Klepetko. There are 14 rows, each of four furnaces, each group of four being driven from a common shaft, and any furnace operated independently by its own friction-clutch. There are four groups of furnaces, each driven by a motor which receives its current from the central power-house.

Professor Hofman[7] gives a careful description of the roasting furnaces of this plant. To this I add certain details of practice.[8] At the beginning of each 8-hr. shift the workman stops the furnace, and removes the lumps of ore or crusts which have accumulated, especially on the rabbles and roof of the third or "cutting" floor and on the roof of the fourth floor to which they adhere. The lumps thus removed furnish material well-suited to blast-furnace smelting. Then, starting the furnace, the few remaining lumps are taken out as they are swept round by the rabbles. Finally the doors, except the bottom ones, are closed, and the furnace resumes its roasting. This work takes about an hour. The side drop-holes of the even-numbered hearths, each situated in front of a door, are cleaned by means of a 1-in. chisel-pointed bar 4 ft. long, and having its cutting-

[7] Notes on the Metallurgy of Copper in Montana., *Trans.*, xxiv., 277.

[8] See also *Mineral Industry*, vol. xii., p. 98.

FIG. 10.—BRIQUETTE-LOADING DEVICE, WITH TRAIN IN POSITION FOR LOADING.

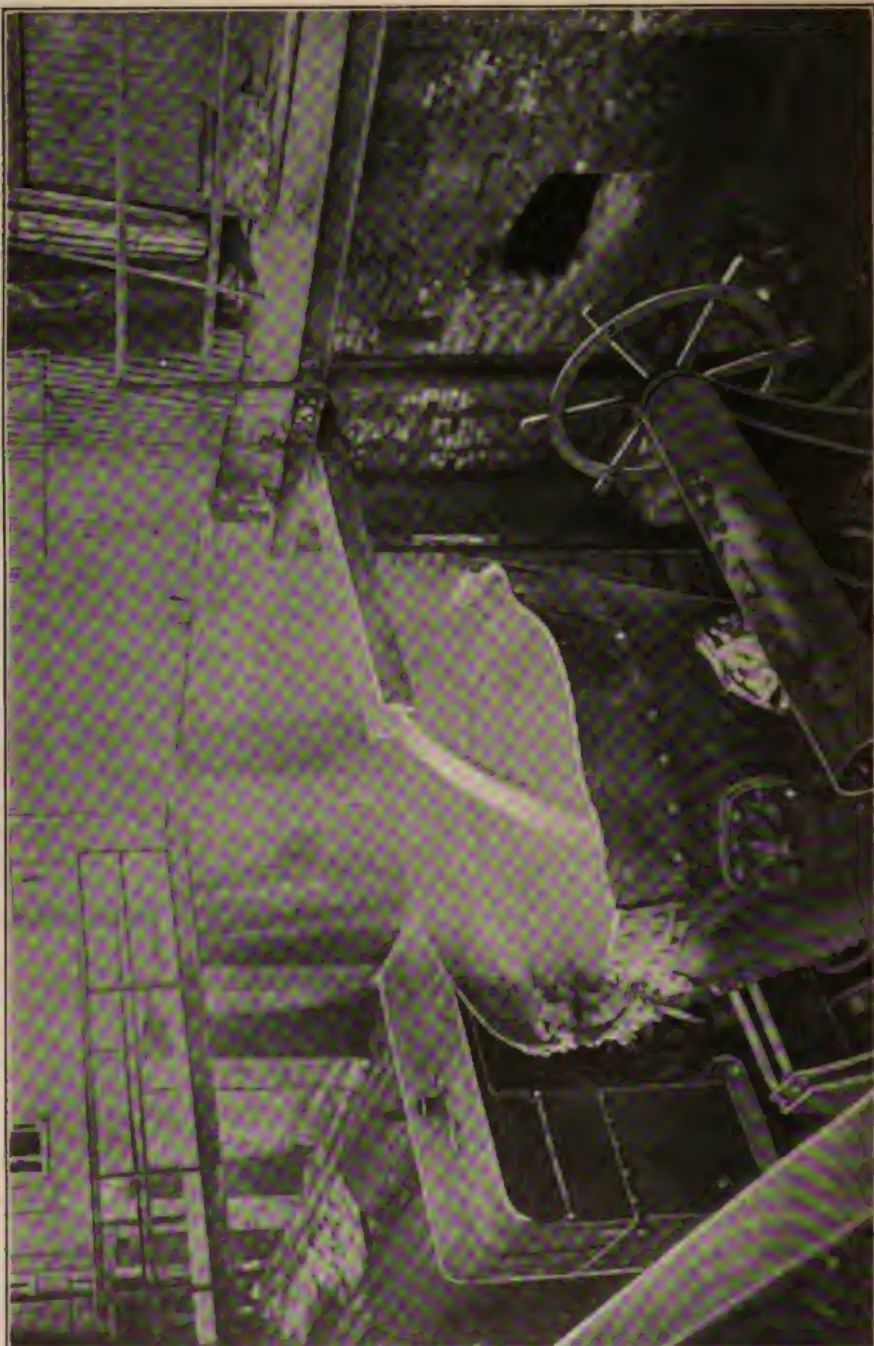


Fig. 11.—Tapping Matte from Reverberatory Furnaces into 10-Ton Ladle.

end curved so as better to reach the sides of the drop-hole. The ore, collecting on the central shaft and at the central draft-hole of the odd-numbered hearth is quite easily removed because of the water-cooled surfaces to which it adheres. In the older installation it was customary to draw the flue-dust from the cross-flue to the calcine-hopper of the furnace. Whenever calcines were drawn off, this flue-dust would escape from the hoppers and act with corrosive effect upon the skin of the workman. The cross-flue was accordingly made over with a hopper-bottom, by which the flue-dust, as it collected, was quietly withdrawn to calcine-cars, and sent back to be again fed through the furnace. This did away with a serious difficulty in operating.

The cross-flues are made of 0.25-in. plate-steel, but they are being so corroded that they are being replaced by flues of brick, having also hopper-bottoms for the convenient removal of the flue-dust. The rabble-blades are 8 in. long and wear to 6 in. before being replaced. When new, they clear the hearth by 2 in. The central drop-hole allows 16 in. between its edge and the shaft. The ore, plowed by the rabble above, drops upon the shield of the next lower rabble-arms at a point midway between them. In so doing, it showers down through the ascending air, which actively roasts it, but, at the same time, this air-current carries away the finer particles of the ore as flue-dust. Hence the considerable portion of that material made, which varies from 3 to 5 per cent.

When a furnace is to be shut down for repair, the feed is stopped and the hearths are emptied by the continued operation of the rabbles. Upon starting up again, about two firings of wood are put on the bottom and fifth hearths. This is followed by coal. When the wood is gone the rabbles are started, as well as the feeding of fresh ore until it comes down to the fourth or fifth hearth. At the same time coal is added to the hearths as they heat up, until the furnace has become sufficiently hot to start the burning of the ore. The heat creeps up and the furnace gradually gets into operation.

The sulphur left in the roasted ore, based upon a capacity of 40 tons daily, is from 6.5 to 8.5 per cent., but preferably of 7 per cent. The charge consists of 27.5 tons of fine concentrates, 1.25 tons of finely crushed limestone, 1.25 tons of returned flue-

dust. The actual output, however, is as high as 47 tons daily. The concentrates may be replaced, in part, by fine screenings from first-class and fine table-concentrates. Fig. 12 shows the progress of the roasting on the successive hearths. It shows that about the same duty is performed by each hearth after the first.

The gases escaping from the upper hearth have a tempera-

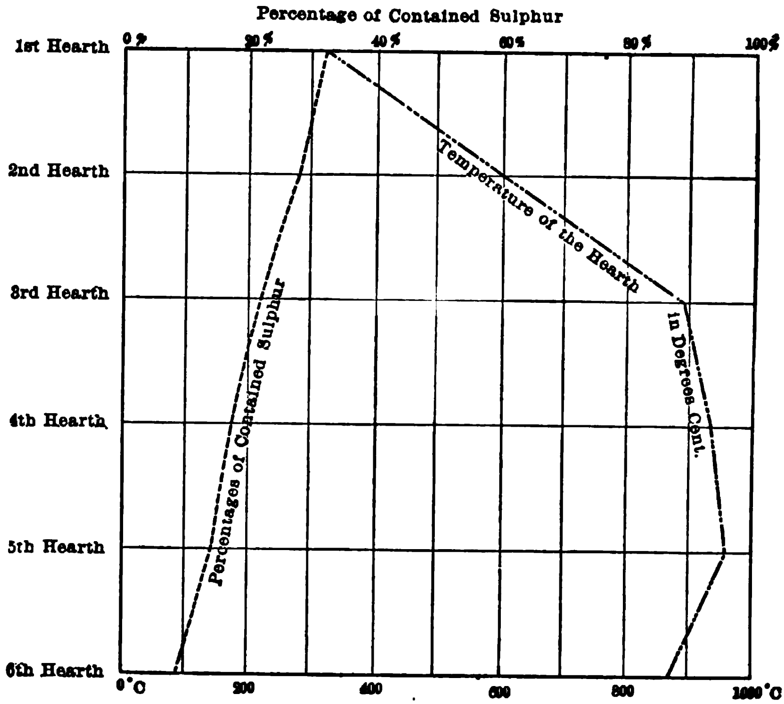


FIG. 12.—PROGRESS OF REACTIONS AND FLAME-TEMPERATURE OF THE McDOUGALL ROASTER.

ture of 315° C. and contain 2.25 per cent. of SO_2 by volume. By the time they reach the flue-chamber they have cooled to 117° C. The appearance of the roasting at the different hearths is as follows:[9]

On the first hearth, the ore, dropped at the circumference, and containing 8 per cent. of moisture, is drying-out, but attains to no visible heat. Entering the second hearth it still looks dark, but showing a blue flame by the time it reaches the

[9] *Trans.*, xxxiv., 277.

borders of the hearth, where it is 600° C. On the third hearth, some sparks show where the rabble passes, together with blue flame becoming hotter, with more abundant sparking, and with a flame-temperature of 900° On the fourth hearth, the sparking has ceased, the ore having attained an orange heat. In falling upon this hearth from the one above, the ore, as it showers down, burns freely, and, undoubtedly, the roasting is hastened, even by this momentary, but thorough, exposure to the ascending air. On the fifth hearth, the sulphur is leaving the ore, the discharge temperature being less than the entering one; that is, it is brighter near the outer periphery. Here the maximum temperature of 960° C. is attained. On the sixth, and final, hearth, the heat has become uniform but lower (860° C.). As the ore leaves the hearth it seems brighter, but speedily cools off to 660° C. as it falls, smoking freely, into the hopper. The calcines are withdrawn rather promptly from the hoppers, so that, by the time they enter the reverberatory furnace, they will average 420° C. The Evans-Klepetko type of roaster, here used, has water-cooled rabble-arms, but it has been found that they abstract but little heat, and in no way hinder the roast. Ore, sticking to the water-cooled surfaces, adheres but lightly, and is easily removed. The percentage of sulphur given in the roast-and-temperature diagram, Fig. 12, is 31.0, but, in general, the average is 34 per cent.

In considering the rate of roasting, the amount of sulphur removed is about the same on each hearth. However, the velocity of expulsion of sulphur should decrease in the ratio of the quantity remaining, much as interest payments decrease on deferred payments. Interfering with this principle is the fact that much heat is used in the expulsion of moisture on the upper hearth, and that the ore, which needs to be heated to a certain temperature (300° C.) before it gets started to roasting, fails to get such a start. On the lower hearth, roasting still proceeds actively, because, at that point, the ore gets air which is quite fresh, while the escaping gases contain SO_2 to the extent of 2.25 per cent. of their volume, or 5 per cent. of their weight. No doubt, tonnage could be increased by blowing-in hot, fresh air at the upper hearth, but this would be adding to the expense, so that it is just as well that it is principally a drying-hearth. The ore takes more than 8 hr. to pass through

the furnace. To the ore has been added 4 per cent. of fine limestone, the calcines also containing 2.5 per cent. of CaO.

The composition of the escaping gases is:—

	By Weight. Per Cent.	By Volume. Per Cent.
SO_2,	4.95	2.25
SO_3,	1.46	0.53
O,	19.60	18.45
N,	74.00	78.77

Thirty-two pounds of air is needed per pound of sulphur, and, since 13.3 lb. of the latter is burned-off per minute, there is needed in that time 6,384 cu. ft., which passes up the central hearth-opening at the rate of 8.8 ft. per sec.; hence, the quantity of flue-dust produced amounts to, at least, 5 per cent. A screen-analysis shows the fineness of the product, viz.:—On 10-mesh screen, 9.7; between 10- and 30-mesh, 25.3; between 30- and 80-mesh, 30.7; passing 80-mesh, 33.4; total, 99.1.

2. *Reverberatory Furnaces.*—There are seven reverberatories, the largest of the kind in the world, placed in two buildings. Each furnace supplies waste heat enough for two 300-h.p. Stirling water-tube boilers. The gases, after passing through the boilers, are conveyed by the reverberatory flue to the main flue. Whenever it is desired to clean the boilers, a bye-pass flue conveys the escaping gases direct to the reverberatory flue, the connection through the boiler being meanwhile shut off.

A sectional plan and elevation of this style of furnace is given in Fig. 13, and the details of construction are as follows:—Length of hearth, No. 1, 115.8 ft..; of Nos. 2, 4 and 5, 102.5 ft.; and of Nos. 3, 6 and 7, 112.5 ft.; all hearths are 19 ft. wide, and have fire-boxes, 16 ft. by 7 ft., or 112 sq. ft. area. Referring to Furnace No. 1, Fig. 13, the outlet-flue at the neck is 60 by 38 in., or of 16 sq. ft. area. The skimming door, 12 by 15 in. wide, has its skim-plate 4 in. above the hearth at that point. The hearth, however, has a slope of 8 in. toward the matte tap-holes. At 24 ft. from its front end, the furnace begins to draw into the jamb, where it is 7 ft. wide and 4 ft. high to the crown of the arch. The rise of the arch is 1 in. to the foot, or at the middle section 19 in. In the roof there were 10 transverse expansion-joints, 3 in. wide, or 30 in. in all, left in the furnace when built. These, however, are now each a little more than 1 in. when the furnace is cold. In the bridge

itself there are three transverse expansion-joints, each of 4 or 5 in., which close up when the furnace is fully heated. The bridge is 4 ft. across, and is 27 in. above the hearth and 24 in. above the grate. It has a hollow conker-plate through which air passes by a ventilating passage to the draft flue, thus keeping the bridge cool. At this end of the furnace the height from the hearth to the crown of the arch is 6.7 ft. Twenty checker-holes, each 3 by 3 in., provided for the admission of air, are located transversely to the furnace over the fire-bridge.

In some of the furnaces additional checker-holes have been made at the front of the fire-box for additional air, but for other furnaces this additional supply of air is not needed. In order

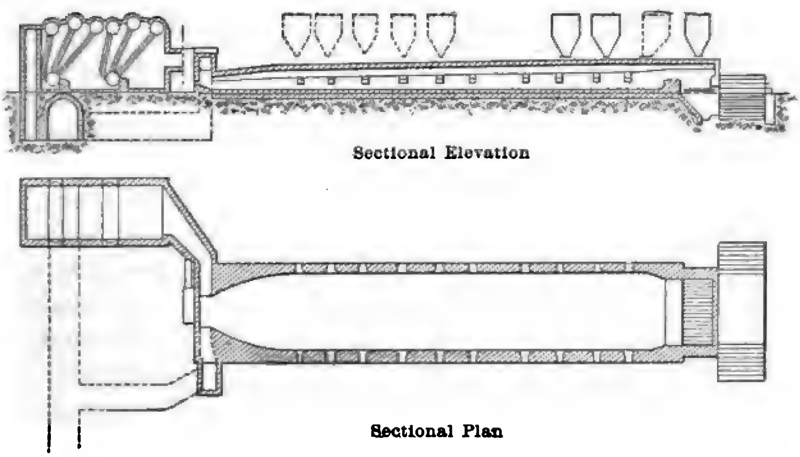


FIG. 13.—REVERBERATORY FURNACE NO. 1, HAVING 115.8 FT. LENGTH OF HEARTH, WITH WASTE-HEAT BOILER-SETTING.

to determine the height of the coal in the fire-box, two circular stoke-holes, 12 in. in diameter, are placed in the front wall of the fire-box, and these opening are closed by wheel-doors. Over the middle line of the fire-box are four charge-openings, 12 in. square, through which the four coal-hoppers discharge into the fire-box. There are ten side-doors, each 8 by 15 in., with sills 18 in. above the level of the skim-plate at the front. The sides of the furnace and the fire-bridge are stepped off for several courses on the inside, thus strengthening the lower portion of the walls and the bridge. There are four charge-openings in the roof, each having circular covers. Through these openings the charge from the two hoppers above drops into the furnace.

The operation of these furnaces is as follows:—In the fire-box of a furnace, which has been shut down for repairs, a fire of wood is put, followed by an increasing firing of coal, until, in 48 hr., the first charge may be dropped in. As fast as charges are melted, others are added, until the furnace has been filled. The furnace takes from 10 to 15 days to get up to its full heat. The charges of 15 tons are put in, on the average, every 80 min., 10 tons being dropped from the first hopper and 5 tons at the second one, 90 ft. from the front of the furnace. It must be noted that the charge drops upon a bath of a minimum depth of from 3 to 4 in. of matte with 8 in. of slag above it, so that there is little chance of the new charge sticking to the hearth. The hot calcines, of which the charge is principally composed, spread out less than commonly represented. There is, however, a movement of the entering charge towards the front of the furnace, in consequence of which the ore may be observed floating down in two ridges towards that end, and gradually spreading out. Heat is taken up not only from the flame, but also from the highly-heated molten bath of the furnace, in consequence of which, fusion proceeds rapidly.

Before dropping the next charge, the side door near the hoppers is opened, and a rabble inserted to determine that no unfused material remains. It sometimes happens that some of the charge becomes agglomerated, and, moving down towards the front end, escapes fusion. These "floaters," as they are termed, are moved up toward the fire-bridge by inserting a rabble at the proper doors, so that they are brought to the hottest part of the furnace and then fused; or, better, a pipe is inserted under them by which the matte just under the floater is bessemerized, and the mass melted at the increased temperature resulting. Skimming is performed every 4 hr., care being taken, however, to do it not less than 45 min. after a charge has been dropped. It takes about 15 min., the amount run out being from 45 to 50 tons. The slag is granulated in water, and is run to waste by a launder to the dump. This operation, called skimming, is rather a tapping, the rabble being used to hold back and control the speed of the outflowing stream of slag. A rabble with a 5- by 9-in. blade and a 12-ft. handle is used, and sometimes a larger one, having a 6- by 16-in. blade. The slag runs through a settling-pot or trough, 7 ft. long, 24 in. wide

and 18 in. deep, intended as a safeguard against a possible escape of matte. The slag adhering to this pot is called pot-slag, and is sent to the blast-furnaces, since it may contain drops of matte. When as much as 200 tons of matte has accumulated in the furnace, it is tapped off, according to the amount of matte needed at the converters. Fig. 11 is a view of matte flowing into a 10-ton ladle from two reverberatory furnaces, 80 ft. distant. The compressed-air locomotive is coupled to the ladle-car, ready to move it when full. Quite commonly the matte is tapped from two furnaces simultaneously, the runner or launder, 80 ft. long, branching to the adjacent tap-holes of the two furnaces. These tap-holes, two to each furnace, are at the hearth-level. The plugging of a tap-hole is done with a stopper-rod or dolly, having a button of 4 in. diameter, on which is stuck a conical clay plug. This is inserted by one man, whose efforts are seconded by another, who strikes the end of the dolly with a heavy hammer, to enter the plug effectually into the tap-hole.

Coal is charged into the fire-box about once in 40 min., dropping in 3,000 lb. of coal at the four charge-openings. The level of the coal is found by feeling it with a rod introduced through the stoke-openings at the front of the fire-box. A mica-covered hole, located in the outlet-flue of the furnace, can be observed 125 ft. away by the fireman, who regulates the firing of the fuel by observing the appearance of the flame at this hole. The coal is carried on the grate to the height of the bridge, or about 24 in., and a clinker-bed is permitted to form on the grate-bars. These bars, 2 in. square and 6 in. centers, permit a good deal of ash and unburned coal to fall through. The dropping of these materials is constant, the coke amounting to 10 per cent. of the total coal used.

About monthly it is necessary to patch or fettle the furnace near the fire-box end, where it is subjected to the greatest action of the fire. This is known by looking in at the slot of the fire-bridge where the conker-plates are observed becoming red-hot. Repairs having been determined on, the matte is allowed to accumulate in the furnace to near the level of the sill of the skimming-door. Slag is tapped and skimmed close to the matte, and then the latter is tapped dry from the furnace. Such a large amount of matte will fill a train of 16 ladles. To take care of

it, preparations have been made by having withdrawn matte just before from the blast-furnace settlers or fore-hearths. Thus full attention can be given to this supply at the converters; at the reverberatory-half the matte is tapped off into ladles and covered, the remainder is then treated in the same way. The first three side-doors of the empty furnace are opened and about 20 tons of sand, used for fettling, thrown in against the corroded sides, as well as placed there by means of paddles. To tap the matte and to repair the furnace requires more than 8 hr., after which the doors are put up, the fires urged, and new charges added until 250 tons of ore has been put in. About once in 8 months it becomes necessary to repair the furnace fully, when it is tapped dry and allowed to cool off until it is possible for the masons to enter. This waiting may be lessened by admitting a blast of air from a fan to ventilate the portions of the furnace where the repairing has chiefly to be done, viz., the 25 or 30 ft. at the fire-box.

These reverberatory furnaces can smelt from 250 to 325 tons daily and may be termed 300-ton furnaces. They burn from 55 to 60 tons of coal in 24 hr., or 21 per cent. of the charge. It must be remembered that about 10 per cent. of this, however, is recovered in the cinders as coke. At $4.50 per ton for coal this would make $1 per ton of charge treated, to say nothing of the 600 h.p. of steam obtained from the waste gases. On account of the large body of matte and slag carried in the furnaces, the variations of temperature are less than in smaller ones. Skimming or tapping is all done at the front door, where the entering air will not cool off the furnace. Care is taken to lute up all openings, and upon the cooler front-half of the furnace-arch, to carry a layer of 3 in. of sand to retain the heat and to stop every crack. When the sand is removed at any spot upon the arch, red-hot brick shows itself. The charge being dropped near the fire-box end, the dust has a chance to settle in going the long distance of 100 ft. through the furnace, so that the loss by flue-dust is small. With a furnace-width of 19 ft. distant from the center-line of the furnace and hence far from the heat, the corrosive action is less than in a narrower furnace. The company makes its own fire-clay and silica brick, the latter being largely used in these furnaces, for both walls and roof.

A type charge of these reverberatories consists of calcines, limestone (put into the charge at the McDougall roasters), and flue-dust, containing: SiO_2, 26.1; FeO, 31.3; CaO, 2.9; S, 8.1; and Cu, 9 per cent. The slag contains SiO_2, 37.8; FeO, 38.6; CaO, 4.6; Al_2O_3, 6; and Cu, 0.37 per cent.; and the loss of sulphur, by volatilization, is 33 per cent. Corresponding reverberatory-slags at Great Falls, Mont., show Cu, 0.69 per cent.; the higher copper-content, as compared with that of the Anaconda slag, being due, (1) to the lower temperature and hence less fluid slags, (2) to the better settling in the longer furnace, and (3) to the greater amount of lime contained in the Anaconda slag. The matte is tapped, through plates 24 by 24 by 2.5 in., to the matte-launders, which convey it 80 ft. to discharge it to the ladles. The temperature of the matte, as it escapes from the furnace, is 1,035° C. and where it enters the ladle 985° C.

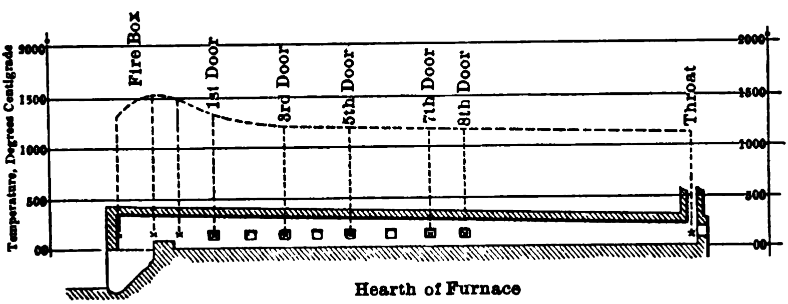


FIG. 14.—LONGITUDINAL SECTION OF REVERBERATORY, SHOWING CURVE OF TEMPERATURE THROUGHOUT THE FURNACE.

Two ladlesful of matte are generally drawn at a time without stopping the flow. It is found that but little matte is spilled in moving the empty ladle into the place of the full one. The best point to which to roast the calcines for good reverberatory work is from 7 to 8 per cent. of sulphur.

Fig. 14 represents a longitudinal section of a reverberatory furnace showing the variations of flame-temperature. After the third door the heat remains, with but little drop, to the front of the furnace. The temperature of the slag, as it issues from the furnace, is 1,120° C. and, as it escapes from the separating trough, 1,060°. At the neck it is 1,100, and, just before it enters the boiler-tubes, 950°. After passing through the boiler, the cooled gases have a temperature of from 330° to 350°. The draft increases progressively from the fire-box, where

it is 0.50 in., to the flue entering the boiler, where it is 1.25 in. of water.

As the charge drops into the furnace there ensues an active ebullition and escape of SO_2 gas, so that the escaping gases of the furnace contain 2.28 per cent. of SO_2 during the first period of 10 minutes. In the second and succeeding 10-min. periods there is approximately 1 per cent. escaping. At the same time but a trace of SO_3 is to be found. Therefore, in this case, the idea that fusion with the silica of the charge produces sulphuric anhydride must be abandoned. The principal reaction is, $FeS + 3\ Fe_2O_3 + 7\ SiO_2 = 7\ FeSiO_3 + SO_2$. Of the 8 per cent. of sulphur contained in the calcines, one-third is thus evolved, the remaining two thirds going into the matte. The matte-fall is 21.5 per cent.; the matte containing 40 per cent. of copper.

XI. Converter-Plant.

The converter-floor has one end, the lining-floor, reserved for lining and drying-out the converters. On the remainder of the floor, space is reserved for the operation of 10 stands or stalls of converters, and for handling the slag and copper. The entire space of this floor is commanded by two 65-ton traveling-cranes intended for handling the converter-shells, which, newly lined, weigh 42 tons, also the slag- and metal-ladles. At one side, adjoining the lining-floor, is the lining-room in which are the crushers and wet pans for preparing the lining or ganister for the converters. On the other side (the casting-floor) are situated two copper-refining furnaces 14 ft. by 22 ft. 8 in. and one 14 ft. by 28 ft. hearth-dimensions, and having fire-boxes 5.5 by 7 ft. of 38 sq. ft. area. The furnaces are provided with endless-chain anode-casting machines, and are filled with the molten converter-copper poured in from 5-ton metal-ladles. The converter-slag is also poured by the 5-ton ladles into a Howden slag-casting machine, which delivers it, suitably cooled by water-sprays, to hopper-bottomed railroad-cars. The converters are charged by means of 10-ton matte-ladles which are brought in on an elevated track, and which are poured into launders leading to the mouth of the converters.

Construction.—These converters are of the barrel-type, 8 ft. in diameter by 12 ft. 6 in. in length, and each of 10 tons capacity. Their average charge is 9 tons, but when nearly eaten out they

will take a charge of from 12 to 13 tons. They are operated by hydraulic power under a pressure of 400 lb. per sq. in., actuating the usual vertical rack and sector. When freshly lined, the cavity of the body of the converter is 6 ft. long at the top, 8 ft. 4 in. long at the bottom, 4 ft. wide and 3 ft. 8 in. deep and of 80 cu. ft. capacity. In the cover this cavity tapers to the spout 2 ft. 6 in. in diameter. The ganister, or lining, consists of siliceous ore of from 70 to 85 per cent. of silica, together with values in copper, gold and silver. To this are added, to produce the necessary adhesion, pond-slimes made by the concentrating-mill, which resemble clay, and contain 60 per cent. of SiO_2 and 2.6 per cent. of Cu. Sometimes the siliceous ore with 70 per cent. of SiO_2 will carry as much as 8 per cent. of iron, quite materially diminishing its efficiency as lining-material.

When the used-up converter-shell has been removed from its stand, the cover is taken off, and water is run into the body to cool it, so that it may be properly trimmed from projecting crusts, etc., preparatory to relining. If necessary, the 4.5-in. brick lining of the shell is repaired. The body, having been taken to the relining-stand, receives the ganister, which is dumped into it by barrow-loads in layers, each layer being rammed by means of a compressed-air rammer, resembling an Ingersoll rock-drill. This rammer, having a 32-in. stroke, and weighing two tons, is suspended from a swinging jib-crane, so that it can be moved over the surface to be rammed. The bottom is brought up to within 6 in. of the tuyere-openings. The form or mold for the cavity is now set in place and filled round with ganister, which is rammed solidly as before. Formerly the ganister was made with water into an adobe, but now it is so stiff that it takes the powerful blows of the rammer to compact it. The filling having been completed to the top of the body, the mold, made in five wedge-shaped pieces, is withdrawn. The top is lined around a form in the same way, and, to hold the lining in place, chaplets, spaced 12 in. apart, are provided projecting from the interior surface of the shell. Finally, the top and lining are bolted together, the joint being made with adobe soft enough to compress throughout the joint. The weight of material thus added exceeds 16 tons, and the operation of lining is completed in 1.5 hr. A converter, thus lined,

will last 6 charges or pourings of copper on an average, or 2.66 tons of ganister used per charge. The lined converters are now moved over to the opposite side of the floor, where they are dried out and heated preparatory to use, firing first with wood followed by coal. The firing is promoted by air blown in at the tuyeres from a small electrically-driven Roots blower.

2. *Operation.*—When dried, the converter is set in its stall and air turned on for a few minutes to burn up the fuel remaining in it. It is next turned down to dump out the ashes, then set in position to take its charge of matte. When the matte-ladle is ready this operation takes 5 or 10 min., the temperature of the outpouring matte being 900° C. In the older installation, the matte-launders were brought round to the front of the converter to be filled in receiving-position, after which the blast was put on as they were brought into blowing-position. At present, the launders are being changed and shortened, conducting in the matte while the converter is in blowing-position. Of course, it is necessary while charging to admit the air, in order to keep the matte out of the tuyeres. However, the short launders are preferable, as they keep themselves clear of accumulating matte, and the chances of spilling are lessened. The first charge of from 7.5 to 9 tons is all the newly-lined converter will take. The average time of blowing a straight, single charge of reverberatory-matte may be given as follows:—To the first skimming for slag, 43 min.; to the second skimming, at the stage of white metal, 60 min.; and when blown to blister, 125 minutes. Under ideal conditions, and with a straight, single charge of blast-furnace matte, the following times have been attained: to the first skim, 49 min.; to the second skim, 125 min.; and to copper, 95 min. The first charge having been poured, 1,000 lb. of siliceous ore is added in a boat or scoop handled by the crane. Matte is run in on this material, which has adhered, in part at least, to the interior surface of the converter. Blowing at once proceeds, the siliceous ore saving the lining to the extent to which it has been able to satisfy the FeO set free in the blow. As the charge becomes hot, a good deal of so-called "dope" consisting of slag, matte, scrap-copper and sweepings, is put in. This is melted, lessening at the same time the intense heat of the reaction. These operations lengthen the time to 135 min. on an average, and, with 10 stalls in operation, from

65 to 90 charges are put through in 24 hr. While the average life of a converter is equal to six pourings of copper, a lining may, at times, last to as much as from 12 to 15 pourings. Forty-per cent. matte is commonly used, yet as low as 30-per cent. has been tried, but it makes less copper and takes a longer time to blow. Allowing an average of 75 charges daily of 9 tons each, 675 tons will be converted in 24 hr., producing from 40-per cent. matte 250 tons or 500,000 lb. of metal. As successive charges are put into a converter its capacity increases by the corrosion or eating-away of the lining, the charge which it will receive increasing relatively until it attains to 12 tons.

By this time, operations have been pushed as far as is possible, and if the converter seems in danger of breaking-out, the charge may be removed in ladles and poured into other converters. It often happens that regular charges, also, are treated in this way, blowing the matte to the first or second skimming and removing it in ladles to another converter, when the original converter takes a fresh charge of 40-per cent. matte, and does not finish its own charge to copper. Spillings and cleanings from the converter sometimes accumulate beneath it. This runs down upon the ground, covering over a piece of wire rope or a chain, which has already been laid there, and to which it adheres. The crane lifts the mass by means of the imbedded chain, pulling it from beneath the converter and depositing it on a 4-wheeled bucket or car. The car is run within reach of a 10-ton travelling crane which commands the casting-floor. The crane takes it to where it can be broken up by a drop-weight and so be made ready for recharging, either to the converter or to the blast-furnace. Whatever material, either sweepings, matte or scrap-copper of sufficiently high grade, is available, is preferably returned to the converters. Continual blowing from the converter into the hoods causes an accumulation of solid material which strikes the interior of the hood, falling down to the bottom of it at the floor-level. This material, about 24 tons daily, or 5.5 per cent. of the matte treated, is cleaned out and used as " dope " for the converters. The ladle, intended for the transfer of copper to the refining-furnaces, is lined with finely-ground ore plastered on its interior to the depth of 4 in. This ore makes it easy to remove the skull, and also retains the heat of the copper. In the older practice, it

was customary to blow a charge to white metal and then run in another charge, the whole being then finished to blister, the operation being called "doubling." Charges are seldom doubled at present, the course preferably pursued being, either to finish the original charge to copper, or to bring it to the stage of white metal, then distributing it to other converters, as above.

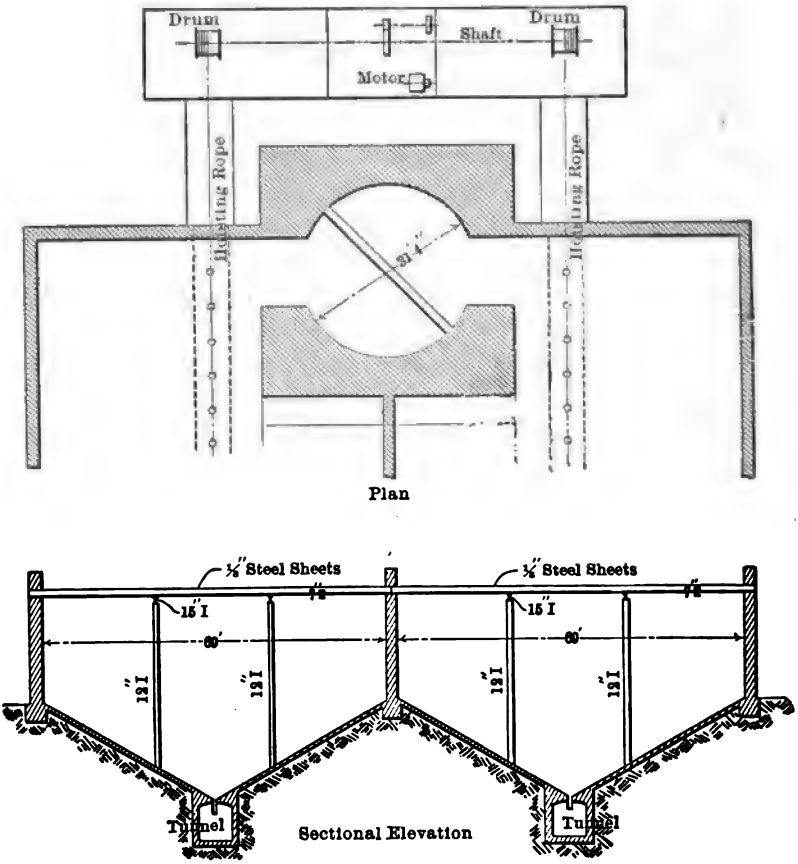


FIG. 15.—PLAN AND SECTIONAL ELEVATION OF MAIN DOUBLE FLUE.

XII. FLUES AND STACKS.

The elaborate system of large flues and stacks at the works has been elsewhere described.[10] Fig. 15 shows a section and a plan of the double flue, and the location of the double hoist. At the apex at the bottom of both the single and the double

[10] *Engineering and Mining Journal*, vol. lxxvi., p. 962.

portions of the main flues there are 315 outlets spaced every 10 ft. of its length. These outlets are controlled by slides. A covered charge-car running in the tunnel can be spotted under any one of these outlets, and by means of a canvas sleeve-connection the flue-dust can be drawn quickly into the car. The car is then lowered to the beginning of the main flue, where it is transferred to a platform-hoist by which it is raised to the arsenic-plant, or to the track which takes it away to be briquetted for the blast-furnace.

In spite of the pains and expense to which the company has been to insure a thorough and harmless disposal of the gases arising from the operations of the plant, a raid has been made upon it by many of the neighboring ranch-men with a view of enriching themselves by compensation for alleged damages which they still claim they incur from the fumes. These people may be divided into three classes: (1) those who realize that they are not being damaged and who, consequently, make no claim against the company; (2) those who ignorantly, but honestly, believe they are damaged; and (3) those who, while they do not honestly believe this, still make a claim for the reward that there may be in it. I have indirectly experienced the effect of such an attack upon a company, normally liberal in imparting technical knowledge of its operations, which has caused it to be reticent where it otherwise would not need to be. The advance of scientific knowledge and the cause of education is often hampered by the greed of men intent upon personal aggrandizement.

In order to show the baselessness of such a claim, the following estimates of the quantities and dilution of the gases has been made from their analyses, and from those of the ores smelted.

Gases per minute:

	Pounds.
48 McDougal roasters, . .	25,600
3 large, 1 small blast-furnace,	12,000
6 reverberatory furnaces, .	6,200
10 converters, ...	2,400
Gases entering main flue, . .	46,200 equalling 693,000 cu. ft. per min.

The total sulphur evolved in 24 hr. is 494 tons, which works out in the gases as 1.5 per cent. of sulphur or 3.0 per cent. SO_2 by weight (1.37 per cent. by volume).

The velocity of the air in the single main flue is 6.9 ft.; in the double flue, 3.45 ft.; and in the stack, 16.45 ft. per second.

If the outer air is still, the smoke, shot up at this velocity, dissipates itself largely in the upper regions. If the velocity of the wind is high, the smoke is rapidly torn apart and scattered. If the velocity of the wind is moderate, say 10 miles per hr., the smoke will be seen to mount at least as high again as the stack itself, thus reaching 1,000 ft. above the valley. By the time it approaches the ground it has attained a breadth of, at least, 4,000 ft. The velocity of the wind being 880 ft. per min., the new volume will be $1,000 \times 4,000 \times 880 = 3,520,000,000$ cu. ft. per min.

The dilution of the gases is, therefore, from 693,000 cu. ft. per minute to 3,520,000,000, cu. ft., or from 1.37 per cent. of SO_2 to 0.000258 per cent. of SO_2 by volume. Such a dilution is so great that, while a slight smell of gases might be distinguished, it is entirely negligible, so far as injury to animal or vegetable life is concerned.

In the various operations, an amount of sulphuric anhydride, small compared with the SO_2 gas, is also developed. This gas, speedily taking up water from the air, forms H_2SO_4. It will be recalled, in the description of the operation of the roaster, that a portion of fine limestone is added to the charge. The fine particles of this escape to the main flue and neutralize the H_2SO_4, forming calcium sulphate. Sulphates are also formed in the flue-dust with other bases, notably copper and iron. Thus no free SO_3 escapes.

The heat-operations eventually drive off all the arsenic contained in the ore, and the gases, as they cool down, deposit in the flues this element in an oxidized form. The arsenic-bearing flue-dust is treated for the recovery of its arsenic described as below.

XIII. Arsenic-Plant.

Of the total quantity of flue-dust taken from the main flue, from 60 to 80 tons daily, about 22,000 lb. of the finest portion, collected in the double flue, is taken to the arsenic-plant. At this upper portion of the main-flue, under the cooling-influence of the roof, the arsenic-fume is condensed, falling to the bottom of the flue and there mingling with the flue-dust. It is this product which is treated for the recovery of its arsenic.

The cars, in which the dust is received, are covered, and hold from 1,400 to 1,700 lb. of flue-dust, which, as it is received in them, weighs about 55 lb. to the cu. ft. The dust is dropped into the feed-hopper of the Brunton revolving-hearth roasting-furnace of 14 ft. diameter. The charge, as the hearth revolves, is stirred by sets of blades, 33 in all, which pass through the roof of the furnace. The capacity of the furnace is 22,000 lb. daily, and there is to be another one added, doubling the output. The roasting is performed at a low heat, being at the finish of a just visible red (480° C.), the heat being kept up by a wood-fire in a fire-box adjoining the hearth. The hearth itself revolves 10 times an hour, and the dust delivered at the axis is discharged at the periphery, arsenic-free, into hopper-cars set below in a tunnel. Thus the flue-dust is periodically taken away to the reverberatory-plant. The arsenic-fume, escaping from the roaster, is conducted through a flue 240 ft. long, 18 ft. wide and 7 ft. high, to an outlet-pipe connected directly to the main flue. The arsenic-flue is interrupted every 7 ft. by baffle-walls, upon which, and upon the roof of the flue, the crude arsenic condenses and accumulates in crystalline form, containing from 85 to 92 per cent. of crude arsenious oxide (As_2O_3).

When a sufficient quantity of these crystals has accumulated in the flue, the roaster is shut down, and the condensed fume, containing As_2O_3, 85 and Cu, 4.3 per cent. with Ag, 8.1 and Au, 0.025 oz. per ton, is removed for further refining. This operation is performed in a reverberatory roasting-furnace in 6-ton charges, the arsenic being volatilized to be again condensed in another flue, of dimensions like the former one. The residues of the operation, which remain on the hearth, are about 2 per cent. of the whole, and contain 26 per cent. of As_2O_3. The arsenic, recovered in the flue, condenses in large white crystals on the roof and walls, and contains 99.8 per cent. of As_2O_3.

The crystals are now ground in a Sturtevant burr-mill, 30 in. in diameter, and fall into a hopper having a screw-feed which delivers to a second Sturtevant mill for finer grinding. From the hopper of this second mill, having also a screw-feed, the powder is transferred and packed in barrels holding 50 lb., which are periodically jolted by power so as to settle the contents in compact form.

From the 11 tons of flue-dust put through daily, from 11 to 18 tons of arsenic are recovered monthly, being from 3.3 to 5.5 per cent. of the flue-dust. The product finds a ready market, the present price of white arsenic being from 6c. to 7c. per pound.

The workmen are protected against the poisonous effect of the fumes by the use of cotton in their nose and ears, by aspirators worn over the mouth and nose, by not working hard enough to perspire, by washing carefully after working and by anointing the exposed portions of the face with a paint of freshly precipitated ferric hydroxide rubbed on with the fingers.

XIV. Coke-Washing Plant.

The droppings from the grates of the reverberatory furnaces consist of ashes, cinders of sizes up to fist-size, coke arising from the coking of coal as it comes through the fire-bed, and sometimes pieces of coal yet unconsumed. The amount of coked material exceeds 10 per cent. of all the coal fed to the fire-boxes. These droppings fall down into a stream of water, which sweeps them away, the force of the water being sufficient to carry along even the larger pieces of slagged cinder. All passes over a grizzly, with bars spaced 1.5 in. apart, which removes the large lumps. The remainder is sluiced to the coke-washing plant, 350 ft. down the hill, and in front of the reverberatory building. Here, all is received into a V-shaped settling-tank, 20 ft. long by 6 ft. wide, divided in half by a transverse partition. This arrangement serves to unwater the materials, while from two gates at the bottom, intermittently opened (8 times per min.) by the action of the jig, a supply comes out to each of the single-compartment jigs, each 24 by 36 in., with a 9-in. overflow, a 4-in. bed and a No. 4 screen. When the supply-gate of the jig opens, a quantity of material flows out to the jig. This must be closely watched, since either the concentrates (cinders), or tailings (coke) may collect very rapidly. There is a center-discharge for the heavy portion which is sluiced away to the dump. The washed coke next flows by a launder to a 0.25-in. mesh trommel, which takes out a great deal of dirt and ashes as well as a little fine coke. The oversize of the trommel discharges to the buckets of an inclined endless-chain elevator, which takes it to a hopper-bottom

bin located to command the track at the west end of the converter-building. Here, it is drawn off into 5-ton hopper-bottom cars to be taken to one of the stock-bins, whence it is drawn off as needed to be mixed for the briquettes.

XV. Slime-Ponds.

Upon the flat ground, below the works, are located the settling-ponds where the concentrator slimes are collected. On the plan, Fig. 1, showing the track-system, adjoining the concentrator plant is a building 670 by 70 ft. in size, beneath which run six tracks. This building contains a series of settling-tanks, the object of which is to unwater the fine concentrates from the tables, the final overflow therefrom being conducted by launder to the slime-ponds half a mile distant. The space occupied by these ponds is 1,000 ft. sq., and is divided into six rectangular divisions, each of 630 by 300 ft. The discharge of the launders is directed into the ponds, the contained water either flowing away or evaporating. Any one of the divisions may be cut out and its contents removed. To do this a Lidgerwood traveling cable-way is used, stretched from tower to tower across the ponds. The slimes are dug out by a scoop, and piled up at the edge of the division, where they drain. The towers are mounted on wheels, and may be moved like a gantry-crane, to operate over any part of the pond. Near one of the towers is placed a movable hopper-bin, having a track below, by which 5-ton hopper-bottom cars may be brought to the chute of the bin. The drained slimes are transferred by the cable-way to the bins, thence to be drawn off into the cars. These cars discharge their contents at the inclined-bottom bins of the briquette-plant or to the bin of the clay-mill at the converter-plant. The pond-slimes at the old works of the company, when dried, contain more than 5 per cent of copper, an analysis from Hofman's paper[11] being: Cu, 4.8; Fe, 5.1; S, 7.4; SiO_2, 53.4; Al_2O_3, 20.7 per cent. and Ag, 2.8 oz. per ton, being practically a clay, still retaining a portion of the sulphides. This affords a very acceptable binder both for briquettes and for converter-lining, and all the copper is recovered. The slimes from the ponds above described contain but 2.8 per cent. of copper, and 2.6 oz. of silver per ton.

[11] *Trans.*, xxxiv., 268.

XVI. Brick-Plant.

The brick-plant, like the foundry and machine-shops of the company, is situated in the town of Anaconda, two miles distant from the reduction-plant. The brick-plant is devoted largely to the manufacture of silica bricks, which are used extensively in the construction of the reverberatories, as well as for the crucibles and fore-hearths of the blast-furnaces.

For these bricks a local silica rock is used containing SiO_2, 96; FeO, 0.3; Al_2O_3, 2.6; and CaO, 0.6 per cent.

This material is crushed for use in brick-making. For sanding the molds, and for mortar in laying these bricks, a quartz from Dillon, Mont., is used, but, because of its friable nature, it is not suited for brick-making. It contains SiO_2, 97.5; FeO, 0.1; Al_2O_3, 1.7; and CaO, 0.2 per cent.

The quartz rock for brick-making is first crushed through a Blake crusher, and is elevated to a trommel with 0.75-in. holes, the oversize going to rolls and thence back to the trommel, while the undersize passes to a storage-bin. The material is drawn from the bin in barrows, there being added to each load a shovelful of lime-paste, so that 2 per cent. of the mass consists of CaO. This is dumped into a wet-pan, where it is mixed and ground in batches until the larger particles of the rock are no larger than will pass a 0.25-in. hole. From the pan it goes to the molding-table and is hand-molded, using Dillon sand for sanding the molds. The freshly-molded bricks are loaded on pallets, placed on iron dryer-cars, and go to the slow-drying room, where, with a good circulation of air, they are partly dried. At this stage they are re-pressed in power-re-pressing brick-machines, and sent on iron dryer-cars to the hot-finishing drying-room. Here, they undergo a thorough drying out at a high temperature given the room by an elaborate system of steam-coils set just below the floor-level. A good circulation of air through these coils carries up the heat to contact with the brick. The dried brick are then transferred to the down-draft kilns, each having a capacity of 30,000 bricks. The kilns are fired vigorously, it being found that the highest temperature attainable does not warp or fuse the brick, though, of course, the lime binding-material causes enough sintering to ensure sufficient strength and compactness. A variety of sizes and kinds are made, so that, besides the regular 9 by 4.5 by 2.5-in. brick, those

of 12 and 15 in. in length are to be had. These larger sizes are particularly well adapted to the thicker walls and roof of the heavier melting-furnaces now in vogue. Table II. shows the composition of Anaconda silica brick and of other silica bricks by way of comparison. Table III. gives the analysis of Anaconda and of other clay fire-brick, some of which, because of their high alumina contents, are very resistant to basic slags.

TABLE II.—*Composition of Silica Brick.*

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Anaconda	97.2	....	1.1	1.0	....
Anaconda	97.0	....	2.1	0.9	....
W. H. Haws Fire Brick Co., Mt. Union, Pa.	97.2	1.4	0.2	0.76	0.35
Fayette Manufacturing Co.	96.6	0.6	0.55	1.8	0.33

TABLE III.—*Composition of Clay Fire-Brick.*

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Denniff (Anaconda)	74.2	21.7	3.4	0.0	....
Curtis No. 4 (Anaconda)	72.8	23.7	3.0	0.0	....
Acme	54.0	44.0	1.6	1.0	....
La Clede, St. Louis, Mo.	60.9	33.6	4.6	1.6	....
Evans & Howard, St. Louis, Mo.	63.3	33.6	1.9	0.7	....
Harbison & Walker, Pittsburg, Pa. (converter tuyeres)	50.4	42.8	3.7	1.0	....
Garl Craig (Scotch)	72.4	23.4	2.4	0.0	....

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Gas-Producer as an Auxiliary in Iron Blast-Furnace Practice.

BY R. H. LEE, LIBERTY FURNACE, VIRGINIA.

(London Meeting, July, 1906.)

WITHOUT doubt, one of the most frequent and serious annoyances connected with the practical running of a blast-furnace, especially in single-furnace plants, is caused by low steam, in spite of the fact that all boilers at blast-furnaces have grates for burning coal, and that coal is more or less continuously burned upon them, from three to a dozen men being pretty constantly engaged around the boilers as firemen or coal- and ash-handlers.

At times, when the furnace is "tight," all available men are put on to assist the regular firemen; yet sufficient steam cannot be got to keep the engines up to their regular number of revolutions, while the stoves, deprived of the gas which has been sent to the boilers, run cold, so that, when the furnace loosens-up and resumes the regular rate of driving, the blast is very considerably below normal temperature, and a "cold," or at best a "high-sulphur," cast is the result. Again, it often happens that a furnace, running at its best, becomes temporarily a little too hot; the pressure rises; the amount of gas made is diminished; the steam soon commences to go down; and a small scaffold is likely to form before the furnace has been brought back to the proper rate of driving, and thus enabled to take its regular amount of blast. The usual remedy is either to "jerk" the furnace by a sudden, brief intermission in blowing, or to cool the furnace by lowering the heat of the blast; but if the lower blast-temperature be maintained too long, the hearth and descending stock may be cooled below the "critical temperature" mentioned by Mr. Johnson,[1] and the furnace may go to the other extreme, and become cold. This is especially the case when coal or coke, high in sulphur, is used.

[1] Notes on the Physical Action of the Blast-Furnace, *Trans.*, xxxvi., 454.

Possibly a day or more may be consumed in getting the furnace back to normal conditions.

The great value of an abundant blast-capacity in the handling of a furnace was once brought home to me in a striking manner, in the management of a furnace of 250 tons' capacity, working on soft coke and a very fine brown hematite, similar in structure and fineness to the Lake Superior Mesabi ores. It was one of a three-furnace plant; but the gas-mains of the furnaces were not connected. Consequently, when steam was low on one furnace, no help could be obtained from its neighbors, and the engines of this particular furnace were always run at their full capacity. The soft coke and fine ore gave rise to more or less sticking, which was handled in the usual way. During the campaign, the blast-main from the spare engine of one of the other furnaces (95 by 21 ft. in size) was connected with this furnace, so that, while the latter depended ordinarily upon its own boilers and engines, the spare engine of the large furnace could be at once put on, if the pressure of blast began to rise. Since, however, the loss of blast from unavoidable leakage around a furnace increases rapidly with the pressure, it was not sufficient to add merely enough blast from the spare engine to make up for the loss measured by the revolutions of the regular engines; much more than this theoretically necessary amount was always needed. The normal amount of blast used was about 28,000 cu. ft. per min. of from 11 to 12 lb. pressure. The spare engine, a double compound Todd of 30,000 cu. ft. capacity, was generally run at about 20 rev. per min., thus giving about 15,000 cu. ft. extra. As a rule, if the foreman put on the extra engine, as soon as the gauge showed the pressure of the blast to be increasing, 20 min. sufficed to loosen the stock and get the furnace back to its normal "gait;" but if, as was sometimes the case, the pressure was allowed to go up 3 or 4 lb. before it was possible to furnish this relief (the spare engine being at work on its own furnace), then one and sometimes two hours of hard blowing were required. The usual remedies of "jerking" and cutting-down the heat of the blast were discontinued; and the only one used afterwards was the very simple procedure of turning on the spare engine for a short time, upon which the pressure gradually fell to the normal, when the extra engine was taken off.

Under this treatment, the furnace was not only more quickly loosened-up, but, since the rate of driving had not been much reduced, the tonnage suffered but little.

It is true that, under the various conditions of practice, all furnaces do not behave in the same manner, so that adding more blast for a short time may not prove successful in all cases; but situations in which an abundant reserve of blast would be of advantage occur very often, as every furnaceman knows.

A large number of boilers of the best modern water-tube types will not effect this result, because, as soon as the gas-supply to a boiler is reduced, the steam must fall from lack of fuel. Firing with coal, of course, helps to a certain extent; but it does not take the place of abundant gas. Forced draft, with hand-firing, although better than hand-firing with natural draft, is not as efficient as plenty of gas. The automatic stoker avoids the cooling due to frequent opening of charging-doors involved in feeding coal by hand; but it is impossible to push the stokers beyond a certain speed, so that, except in the amount of labor required, the machine has no particular advantage over hand-firing with forced draft, for the rapid raising of steam in an emergency. Moreover, it is useless to add boilers to a furnace-plant beyond a certain limit, because, unless there is sufficient gas to fill the combustion-chambers properly, no advantage is gained. On the contrary, the results are not as good as those attainable with fewer boilers and more gas to each one.

It seems necessary, therefore, to adopt some other means for supplying additional blast at need; and I can see no cheaper or more feasible means than the use of a gas-producer driven by forced draft.

With producers, the amount of coal burned in good practice would not vary much from what is now used. Even the light fires kept on the boiler-grates to keep the gas lit might be dispensed with, since the flow of gas to the boilers would not be checked, and there would be no danger of the flames going out. The net calorific effect of coal burnt under the boilers and in the gas-producers, respectively, is, if not the same, rather in favor of the producer; indeed, the efficiency of carbon burnt in the form of producer-gas is claimed to be from 5 to 25 per cent. greater than that of direct combustion of solid fuel. It is certain, therefore, that no more coal would be used than in

the present way, while the producer would give the added advantage of permitting at all times a perfect control of the amount of gas under the boilers. Moreover, a glance at the following average analyses of producer- and blast-furnace gases shows the greater richness of the former, and the great advantage of having them available, as a portion of the gaseous mixture burned under the boilers.

Average Analyses of Producer- and Furnace-Gases.

	A. Producer-Gas. Volume Percentage.	B. Furnace-Gas. Volume Percentage.
Carbon monoxide (CO),	22.0 to 30.0	25.0
Carbon dioxide (CO_2),	6.0 to 1.5	13.5
Hydrogen (H),	15.0 to 7.0	1.5
Methane (CH_4),	3.0 to 1.5	0.0
Nitrogen (N),	54.0 to 60.0	60.0
	100.0 100.0	100.0

A, from R. D. Wood & Co.'s pamphlet on Producer-Gases; B, from 50 analyses made under the writer's direction.

The arrangements for delivering the producer-gas to the boilers, and the size and form of burners used, would naturally vary according as local conditions demand. Either overhead or underground mains could be used, provided there were proper cleaning-facilities. Separate mains for the blast-furnace gas and the producer-gas should be employed: (1) in order that the producer-gas main could be cleaned without shutting-down the furnace; (2) to prevent the producer-gas from flowing up the down-comer to the top of the furnace, instead of being drawn under the boilers. This would occur only when shutting off the blast, and would be due to insufficient height of the boiler-chimney, though this might be otherwise as high as present practice demands. The latter risk could be obviated by means of suitable valves placed between the boilers and the furnace; but such valves would have to be closed at every step, which would be troublesome, and therefore might be sometimes forgotten.

The greater cost of separate mains and separate burners at the boilers might be advanced as an argument for turning the producer-gas into the blast-main from the furnace to the boiler-plant; but I believe the two objections above noted would, in

the long run, more than counterbalance the saving in first cost resulting from using a single system of mains for both gases.

The use of producer-gas in the stoves, as well as under the boilers, is not suggested as one of the advantages to be secured by having a few producers connected with a blast-furnace. If desired, the producer-gas could as easily be introduced into the stoves as under the boilers; but its use there would be so infrequent as hardly to warrant the expense of installation. The real advantage of adding producers to a blast-furnace plant would be confined to the boilers, where the gain from having an abundant supply of rich gas, under perfect control, would very soon repay the cost of installation by increased output and greater regularity of product.

To a plant of three or more blast-furnaces, gas-producers would not be of as great value as to a single furnace; yet even with three or four connected furnaces, coal must be burned under the boilers; and in this case, also, the gas-producers would have the advantage over the present mode of coal-firing, that a greater calorific effect is obtained from the fuel. In either case, the labor would be a trifle less, and the firing would be under better control, which would mean less variation in the amount of air blown through the furnace, with all the well-known attendant advantages of such regularity.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Methods of Mining, Hauling, and Screening at the Mines of the Aldrich Mining Company, at Brilliant, Alabama.

BY T. H. ALDRICH, JR., BIRMINGHAM, ALA.

(London Meeting, July, 1906.)

INTRODUCTION.

THE Aldrich Mining Co. holds under lease from the Illinois Central R. R. Co. about 14,000 acres, in the East half of Township 12, Range 12 W., in Marion county, Alabama, and owns other lands, of which about 1,000 acres adjoin this leased tract, making a total area of about 15,000 acres, all of which is underlain by the coal-seam upon which the company is operating. This seam is nearly horizontal; and a ravine, diagonally crossing the tract, exposes the outcrop on either side for about 2 miles. The territory has been so divided that nearly the whole of it can be worked out by two collieries.

The mines at Brilliant were opened in the Fall of 1898, and shipments began in the following spring. The original plan was to furnish steam-coal for locomotives to the Illinois Central R. R. Co.; and upon this expectation the investment of capital was made. The field was entirely new; and the softness of the coal at the outcrop induced the belief that it could be very cheaply mined. A contract for the delivery of a large quantity of coal to the railroad was accordingly executed. But with the advance of the entries to increasing distances from the outcrop, the coal proved so hard that it could no longer be drilled with a breast-auger; and the expense of mining became so great that the contract for cheap steam-coal had to be cancelled. It became evident that the work must be done with machinery and explosives, if it could be profitably done at all.

On the other hand, the excellent quality of this coal opened, at the same time, a possible market not specially contemplated at the outset—namely, that of a first-rate coal for domestic and general uses. Since no other deposit of such coal was known to exist on the line of the Illinois Central, or any other railroad

available as customer or carrier, and since the tract controlled by the Aldrich Mining Co. could furnish for a hundred years a large annual tonnage, it was obviously worth while to make extensive experiments, in order to perfect a system of mining, haulage, dumping, etc., which would effect the minimum cost of production—including under "cost" the items (known to all mining-managers as vitally important) of maintenance, repairs, interruptions, superintendence, etc., as well as those of construction, installation, and normally requisite labor. Moreover, it was necessary to a successful system that it should yield a product suited to the special market accessible to us.

It is the purpose of this paper to state with sufficient fullness the conditions of this problem, and the solution reached under those conditions, without going into such minute details as might both transcend the limits of available space and obscure the main outline of the principles followed. It is not assumed that the practice here described would be the best for other localities and circumstances.

The situation which we had to confront comprised three principal questions, involving the best method, respectively, of mining, hauling, and dumping. These will be considered in order.

Mining.

The coal-seam was only 30 in. thick, and almost horizontal in position. It presented no "butts" or "faces," and the coal was so tight between the top and bottom that it could not be shot "from the solid." I have seen chunks, 6 ft. wide and 4 ft. deep, thrown, by the firing of holes containing 40 in. of powder, to such a distance from the face that a man could crawl entirely around them; and yet the coal remained as tight between top and bottom as before. There were no partings or soft streaks whatever. The roof was sometimes sandstone and sometimes slate, usually stratified sandstone. The bottom was fire-clay for about 4 in.; then gritty clay for 10 in.; then sandstone. The clay was too hard to be satisfactorily worked with any kind of machine; and sometimes the sandstone came up to the coal, with no clay between. Although the roof was excellent, and the mines were comparatively dry, mining was very difficult. We tried:

1. The long-wall system, using hand-labor with picks. This

worked well; but the necessary number of skilled miners could not be obtained.

2. The long-wall machine, which likewise gave good results, but was open to the same objection.

3. Shooting the fire-clay from the solid, and then breaking down the coal with the pick.

4. A modified long-wall system, using narrow rooms, driven by hand, and then slabbed with a long-wall machine, which was run up one side and down the other, the face being followed with a slip track.

5. Cutting the bottom with compressed-air "punchers."

6. Under-cutting the coal in the same way.

Experiments 3, 4 and 5 were semi-successful; but the only really successful one was No. 6, in which the puncher cut the coal. When the bottom only was thus cut (No. 5), there was a tendency on the part of the machine-men to keep coming up into the coal; or, perhaps, the following machine-man would cut deeper than his predecessor, thus leaving the bottom in bad condition for laying the track. Moreover, it was difficult to get the men to cut the bottom at a reasonable rate of pay; and sometimes the operation was impracticable, because the cuttings of fire-clay formed a sort of mush which could not be handled.

Commercial Considerations.

Besides the direct cost of mining a given weight of coal, special commercial considerations were involved in our problem. The hardness of our seam prevented us from competing with innumerable other producers of steam-coal, but made us the only producers of high-grade domestic coal within a large region, especially in Alabama. Our lump-coal "stocks" well, not being liable to spontaneous combustion, or to serious decrepitation. After lying for eight months in piles on the ground, it loses, in passing over the same screen, only 2 per cent. This enables us to accumulate at the mines so much of our summer output as our customers will not buy and stock for themselves. (The market-price is higher in winter, when everybody wants coal; and Alabama consumers have learned to save money by purchasing at summer-rates. But the contrary custom has long obtained in Mississippi; and such habits are hard to change.) While we would be glad to make immediate summer-deliveries

at summer-rates, we must stock our own coal somewhere, if our customers prefer not to do so; for, as all colliery-managers know, fluctuations in the labor-force and in output, due to fluctuations in market-demand, are economical evils of the worst class, injuring employers, employees and consumers alike. We have found that by stocking coal at the mines, instead of the yards where it is sold, we can save as much as 40c. per ton—partly in interest on the high freight-rates to local R. R. stations, which we thus avoid paying until the coal is actually called for.

Since lump-coal is our chief profitable product, and, moreover, the size which can be stocked, as above described, with minimum loss, it is obvious that we must produce as large a proportion of lump-coal as possible, and that the size so denominated shall be as small as can be sold to consumers, or stocked without deterioration. This size has been fixed by experience to be that obtained by the use in the screen of round 2-in. holes, as further described below. The maximum production of such lump-coal requires the reduction of the machine-cutting of coal to a minimum. As already explained, we found it better to do the under-cutting in the coal than in the floor. This being the case, it was important to know which machine would give us, as a net result, the largest proportion of "lump," and the most favorable proportions of "nut" and "slack." Our experience thus far has indicated the Harrison "P. G." type as the best for our special case, on account of its ability to make a very low cut. The use of this machine gives us, of the total coal broken, about 65 per cent. lump (worth, say, $2.10 per ton), and 35 per cent. nut and slack (worth, say, $1.10 per ton). As compared with other machines which we have tried, and which yielded a smaller proportion of lump, this might save, upon the mining of 500 tons daily, for 275 days in the year, more than $30,000.

Nature of Motive Power.

The coal-cutting machines are run by compressed air, although electric power is used for haulage. Undoubtedly a large further saving could be effected by the use of electrically-transmitted power for coal-cutting, which would eliminate the serious cost of purchasing, laying, maintaining, repairing and renewing pipes, hose, hose-fittings and valves, besides reducing

the items of fuel and power-house expenses. In so small a seam, the amount of coal won for a given amount of cutting is relatively small; that of pipe-laying per ton is correspondingly large, the distance to be covered with pipes increasing very rapidly; and the pipe remaining permanently in the mine, practically never to be recovered, represents in all $10,000 per 75,000 tons of coal mined. Moreover we have found the efficiency of the power transmitted by compressed air to be small in our practice. The coal burned at the power-house for each of our collieries is approximately 175 tons per month for each 100 tons of coal mined per day. Again, the mine-water rapidly corrodes our pipes and valves; all of the latter constantly leaking. Finally, the workmen habitually turn on the compressed-air, in order to blow the smoke away, after blasting; and it is difficult to prevent this waste of power. These facts warrant the conclusion that, for our particular conditions, the electric transmission of power for the cutting of coal would effect a large saving in running expenses.

Labor-Costs.

As already explained, mining is done by contract, each contractor receiving one machine and one entry, and delivering the coal on a large car for 75c. per ton (or on a small car, where the old system, involving switches, is still in use, at 65c. per ton). He pays his men according to a schedule fixed annually on July 1, by agreement between the company and the men, from which he is not permitted to depart. The labor-union known as "The United Mine-Workers of America," formerly organized in this locality, insisted upon the system followed in Indiana and Pennsylvania, according to which the company pays for the cutting, and the miners contract for the rest of the work—cleaning-up, timbering, track-laying, etc. This system would be advantageous for both the company and the miners, if the latter were loyal and industrious. Unfortunately, in our district, the men were like spoiled children, recklessly disregarding both their own interest and that of their employers, and working or not working, according to their whim. Under the system mentioned, we found that twice as many rooms, and nearly twice as many men were required for a given output, and that this output was very irregular. On some

days, all the rooms would be only partly cleaned, so that none were ready for the machine. On other days, all the rooms would be ready simultaneously, while, of course, the machine was not available for all at once. It was impossible to get the men to clean up the rooms so that they could be made ready for the machine in regular succession; and consequently they were continually wrangling for precedence in this respect. Under these conditions, the output of coal per machine was on one day 30 tons; on the next, perhaps, nothing; and the average was not much more than 15 tons. Under the contract system now in force, the average output is somewhat more than 30 tons per day. A man desiring to leave one contractor and to work for another must either have the consent of the former, or give three days' notice.

The following is the present wage-schedule:

Coal-shooters, $2.50 per day; machine-runners, $0.045 per ft., or $2.50 per day; machine-scrapers, $0.03 per ft., or $1.50 per day; daily wages of drivers (one mule), $1.40; (2-mule teams), $1.65; (3-mule teams), $1.75; track-men, $2.25; miners, $2.25; outside labor, $1.25; blacksmiths, $2.35; helpers, $1.25 to $1.50; car trimmers, $1.25; couplers (boys), $0.90; (men), $1.35; motor-runners, $1.50; dinkey-engineer, $45 per month; weighman, $40 per month,

Hauling.

We tried several systems of hauling, employing at first 1-ton cars, 30 in. high, which were loaded in the rooms. This required 10 in. of bottom to be taken up in the rooms, and switches to be placed at the room-necks. Later, we gained the necessary head-room from the top, instead of the bottom, because the latter, when blasted, came up badly, leaving "potholes," and not lifting in slabs or flakes. Still later, the cars were remodeled, so as to be exceptionally wide and only 18 in. high from the top of the track-rail. This made the place of loading so low that it was impossible to use any end-gate. We experimented with perhaps 100 kinds of gates, using: a sloping iron-plate; a bar across the front; a chain across the front; half an end; and all manner of devices to keep the coal from coming out. All failed, because the lumps were so large, and the space was so small in which to load them. When the

the coal was shot down, the center yielded large flat flakes, while the top and bottom of the seam broke with a cubical fracture, and gave a good deal of small coal, in addition to which the machine-cuttings had to be loaded and hauled out. The coal spilled badly in the gangways, causing many wrecks, much loss of coal, many crippled mules, and great expense for keeping the roads clean and the ditches open.

We tried next a large car, 6 ft. long, 6 ft. wide and 14 in. high, running on a 3-ft. gauge, with the wheels up in the car-body, protected with a cast-iron housing. This was satisfactory in many respects; but, proving clumsy to handle and to put on the track, difficult to oil, and requiring, moreover, the keeping of the track very clean, it was finally abandoned.

We then tried to increase the capacity of the car by running the bottom plank under the axle, instead of over it, and increasing the length, height and width of the car to a maximum. This experiment was also a failure, because the least little lump on the roadway would cause a wreck. Besides, for a product of 400 tons a day, it involved the daily handling of 800 small mine-cars, holding only 1,000 lb. of coal each, and thus required so many cars and mules, besides involving so much difficulty on the tipple, that a larger car was indicated as an absolute necessity. Moreover, by reason of the thinness of the seam, the rooms were worked out so fast that this system had not a sufficient radius of action without serious increase of cost.

Then we tried the old Welsh buggies, delivering the coal to cars; and finally, we adopted a type of buggy made with two rib-irons, four trunnion-wheels on the sides of the irons, and five pieces of plank, with no draw-bars, bumpers or end-gates. (Later, end-gates were adopted, consisting of a plank lifting out between two guides, similar to the tail-gate of a wagon.) These buggies, which were used in the rooms only, had 14-in. wheels, were very light and cheap, could be pushed easily, and were hung so low that the bottom was on a level with the top of the rail, and the miner could load the largest lumps over the sides or ends, without laboriously building up the load. Fig. 1 shows the construction of such a buggy.

This is the system now employed. At the mouth of the room-neck, one "brushing-shot," tearing down 3 ft., is made,

and, when the buggies have been pushed to this point, the coal is transferred with a shovel from the buggies to large cars in

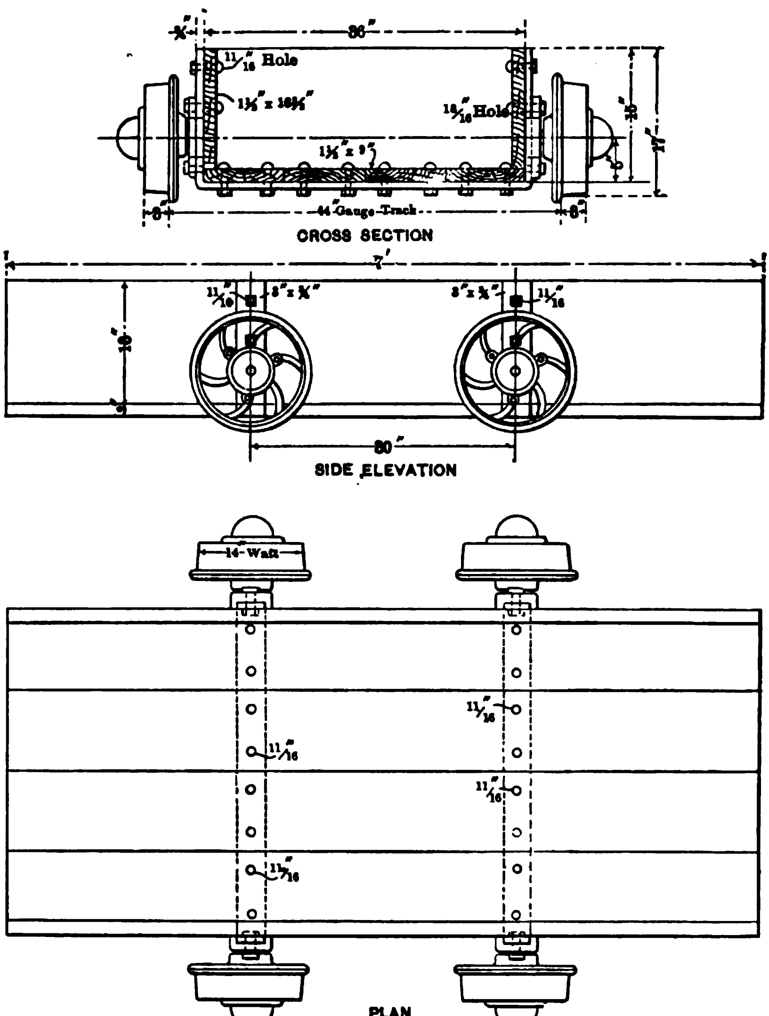


FIG. 1.—COAL-BUGGY. BUILT BY THE DECATUR CAR-WHEEL AND MANUFACTURING CO. FOR THE ALDRICH MINING CO.

the entry, holding 3 tons each, and having solid ends. The construction of these cars is shown in Fig. 2.

The main entry is laid with 25-lb. rails, with splice-bars and bonds; there are no room-neck switches; no coal is spilled in the road-way; no cleaning of track is necessary; and the haul-

ing is done entirely by electric power, mules being dispensed with altogether.

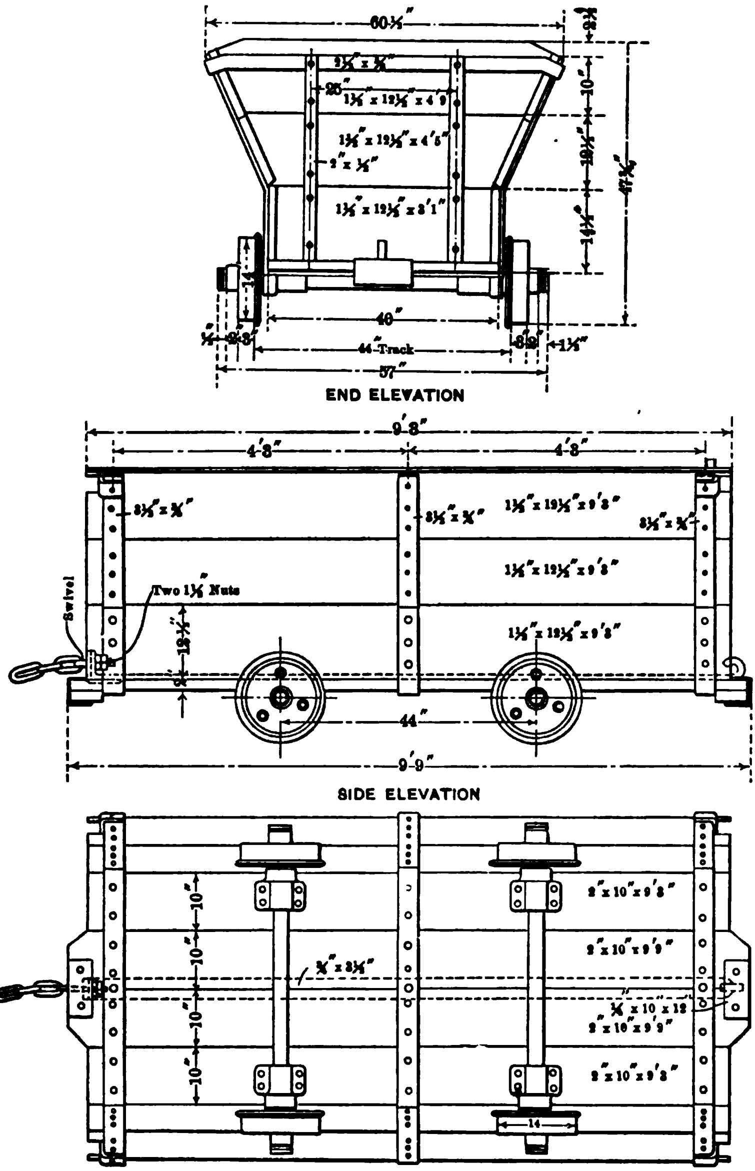


FIG. 2.—THREE-TON COAL-CAR OF THE ALDRICH MINING CO.

As already explained, mining is done by contract. Each contractor takes charge of one machine and one entry, and, as

a rule, turns out 30 tons a day, the company taking the coal from him at 75 cents per ton on the 3-ton cars. Such a contract, delivering 30 tons a day, requires 10 large cars, 5 of which are pushed into place in the morning and removed at noon, when the other 5 are put in their place. The motor makes two trips a day to each entry. On each trip, the front car is a rock-car, having side-dumps, and holding 6 tons of rock, which is about half of one "brushing-shot." With the two rock-cars furnished, the contractor can, therefore, clean up a brushing-shot each day. Since these cars are of the same size as the coal-cars, he can load them with coal if desirable.

The advantages of this system of buggies, combined with large cars and electric haulage, are as follows:

1. The absence of switches makes pipe-laying easy. Sometimes an entry will go 0.25 mile without encountering water, and suddenly there will be so much water in one place that a suction-pipe or a pump must be installed. Under the old system, this pipe might have to go under a dozen switches, at great trouble and expense.

2. No top is taken down and no bottom is taken up in the rooms, since the buggy follows the seam. Under the old system, the "yardage" paid for this work of "room-brushing" amounted to 6.1c. over and above the mining-pay of 65c. per ton, making the total labor-cost 71.1c. per ton, of which the loaders got 20c. Under the present system, 5c. more is allowed to loaders, and 5c. to the contractor, making the cost of the coal on the big car 75c. as against 71.1c. per ton. Experience has shown that, besides receiving more per ton, the loaders load more tons per day. They never have to wait for cars. The large cars spill no coal on road-ways. The cost of the maintenance of cars is smaller, as is also the number of cars required.

3. The smooth main track permits of high speed, thus giving the motor greater range of action, and securing a greater utilization of gang-ways and tracks, in proportion to the repairs inevitably required by lapse of time.

4. Drivers and mules are eliminated.

5. Many fixed charges and contingent expenses, such as mule-feed in time of strike or shut-down, are greatly reduced.

6. Per ton of capacity, the investment in cars is much smaller.

One of the old cars weighed 1,000 lb., held 1,000 lb. of coal and cost $33 made up. One of the cars now used weighs 2,000 lb., holds 6,000 lb. of coal, and cost $47. In other words, the dead weight, formerly equal to the weight of coal, is now only one-third thereof.

7. By reason of the superior design of the present cars, the cost of maintenance per car is no greater than before; and, since the number of large cars per ton of coal mined is much smaller, the actual expense of this item per ton is only one-fifteenth of what it used to be.

8. This system requires no additional excavation. For both sizes of cars, the entry must have practically the same dimensions, namely, a height of 5 ft. 4 in. above the rail and a width of 8 ft. The satisfactory operation of any such system depends, of course, upon the perfection of its details. Some of these will, therefore, be more particularly described.

Car-Wheels.

The wheels of mine-cars are subjected to exceptionally severe wear and rough usage. The cars, having neither buffers nor brakes, are jammed together or jerked apart in hauling, or violently checked by "spragging;" the tracks are not kept in perfect condition or repaired oftener than is absolutely necessary, and the wheels are consequently jolted over irregularities and bad joints, or thrown off the rails by unnoticed obstacles, and rudely jerked on again; frequently they are covered with water; the gangways are dark, and close supervision of the haulage is impracticable; it is not always easy to detect the necessity, or perform the process, of lubrication; and, finally, the employment of as little and as cheap labor as possible is required in the operation of trains. On the other hand, the direct expense of repairs to the cars, and the inconvenience and interruption thereby occasioned (which may amount to a still greater loss), render it vitally important that the car-wheels shall run as long, and require as little personal attention, as possible. The strength of the whole chain of the haulage-system is, according to the proverb, no greater than the strength of its weakest link; and hence improvements in the design of a car-wheel may be as important as much more ambitious inventions. The wheel here described therefore constitutes an

essential element in the success of the general system adopted by our company.

Fig. 3 shows the construction of this wheel, which is a solid casting, having no parts (except the oil-plugs) which can be loosened or detached. The leading purposes of the design are to secure maximum strength for the weight of metal; uniform wear of parts; and facility and certainty of lubrication.

1. By plates, bracing the sides of the rim, a proportional strength, greater than that of wheels with spokes, is secured. Spragging may be provided for by means of a wedge-shaped lug

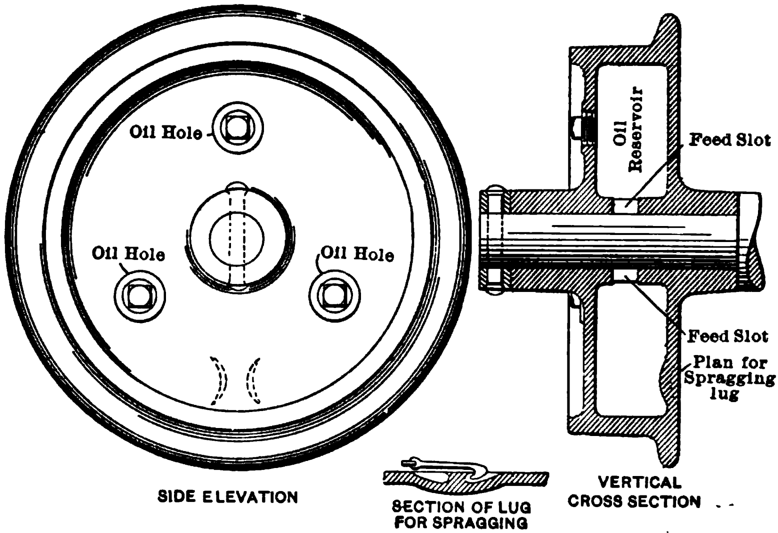


FIG. 3.—SOLID CAST-IRON WHEEL. USED BY THE ALDRICH MINING CO. UPON 3 TON MINE-CARS.

in either web, with a hook, adapted to catch and hold the wheel.

2. Uniform wear, essential to durability, is secured by an equal distribution of strain upon the bearing, and of lubricant upon the surface exposed to friction. The equal strain is obtained by means of a hub presenting an integral bearing-surface, bisected by a vertical longitudinal plane through the center of the tread of the wheel. The pressure per sq. in. is, therefore, the same at all points of the bearing-surface; and the wheel moves in true alignment with the direction of motion of the car, until it is completely worn out. The importance of this feature cannot be too much emphasized. An unequal dis-

tribution of the thrust on the bearing causes a greater wear on one side of the center, tending to a deformation which, however minute at first, is rapidly multiplied, throwing the wheel more and more out of alignment, so that its flange not only cramps and wears the rail, but also becomes increasingly liable to "trip" at switch connections, and to wreck the car.

3. For the purpose of lubrication, the wheel is cast with webs, enclosing a large oil-chamber, which extends from hub to rim, and is so large that three or, at most, four oilings per year will be sufficient. When so great a quantity of lubricant is provided, a method of feeding is obviously required which, while not liable to clog, will supply no more oil than is necessary, and will evenly distribute this supply. This is effected by one or more entirely open and unobstructed longitudinal openings or slots in the hub, leading directly from the reservoir to the axle, and so proportioned as to catch, as the wheel revolves, a suitable amount of the film of oil on the sides of the reservoir, and feed it to the center of the bearing-surface. When packing or waste is placed over or in the oil-ducts, they are liable to become clogged; and this liability calls for that closer attention to the wheel which it is desirable to render unnecessary.

In the present usual practice, the outer ends of the hubs are packed, to hold the oil in, and to protect the bearing against the entrance of grit and dirt. This involves an uneven lubrication, and also prevents early indication of the fact that the wheel has become dry. In the wheel here described, both ends of the bearing are left open, so that the oil, introduced at the center, and flowing evenly outwards in both directions, tends to prevent dirt from working in, and also shows at all times the condition of lubrication. The waste of oil, which should be prevented by a proper adjustment of the feeding-orifices, is easily noted at once; and, when the lubricant has been exhausted, the whole bearing becomes dry at the same time, the fact being patent upon the most superficial outside inspection.

Without dwelling upon other details of this design, I may mention as worthy of notice two subordinate features, which are more important in practice than they look on paper. The first is, that the openings through which the oil-reservoir is charged are so disposed that, if (as happens much oftener than

it ought to happen) a plug is carelessly *not* replaced after filling, there will be no serious loss of oil. The second is, that these plugs are made large enough to prevent their being so battered or twisted off by accidental underground shocks, such as careless wrenching, as not to be easily extracted. Any engineer who has experienced the exasperating necessity of actually drilling-out a jammed plug of this kind will appreciate the value of this feature.

The wheel here described has demonstrated, by long continuous use, the superior durability, evenness of wear, and freedom from the necessity of attention, above claimed.

Car-Couplings.

The couplings of the large cars employed in this system of haulage are so designed as to permit at the tipple the tilting of each car, without breaking its connection with the preceding or the following car, and thus the connection of the train with the motor which pulls it. This problem is not difficult. It was solved in our practice by using, for the large cars, couplings consisting of three links and an eye-bolt, which is held on with jam-nuts, and the shank of which passes through the up-turned end of the draw-bar. The other end of the draw-bar is a hook; and the eye-bolt acts as a swivel.

(See Figs. 2 and 4, the latter of which shows a rock-car, like the mine-car, except that it has shutters for side-dumping. The coupling is the same for both, since the rock-car, if it should happen to be loaded with coal, would have to be dumped by tilting.)

DUMPING.

The tipple (Figs. 5, 6 and 7) is a cylindrical frame, rotating on trunnion-wheels, and so arranged as to permit the weighing and dumping of each car of a mine-train, without breaking the train or disconnecting the motor, and in such a manner that one man only is employed on the tipple, he attending to both weighing and dumping. Incidentally, it was necessary to provide a device which would automatically arrest and hold upon the tipple, for the purpose of dumping, each successive car of a train, while permitting the motor which hauled the train to pass over the tipple, without being thus held and overturned. This was accomplished by causing the retaining-device to en-

FIG. 4.—ROCK-CAR, WITH SHUTTERS FOR SIDE-DUMPING.

FIG. 5.—SCALE, AND TIPPLE DUMPING THE LAST CAR OF THE TRAIN.

FIG. 6.—TIPPLE, WITH SINGLE-TRACK TRESTLE, SERVING MINES ON BOTH SIDES OF THE RAVINE.

FIG. 7.—OVERHEAD TROLLEY, AND MOTOR PASSING THROUGH TIPPLE.

gage the wheel-hubs, instead of the wheel-rims, of the cars, so that the hubs of the larger wheels of the motor would pass above it, and escape its action altogether, without the need of any moving parts, or human intervention, to prevent the motor from being caught and dumped.

This system of continuous weighing and dumping (equally practicable with a steam locomotive) is operated at the mines of the Aldrich Co. with an electric locomotive as follows:

The train of loaded cars is hauled to the dump, and stops for a moment, with the motor on the tipple (the trolley wire running through it), and the first car on the weighing-scale. When this car has been weighed, the motor goes forward, bringing that car upon the tipple, where it is caught and held, while the second car, simultaneously brought upon the scale, is weighed. During the weighing of the second car, the tipple is revolved, and the first car is dumped and returned to position, *without severing its connection with either the motor or the following car.* The motor then advances again, and the second car is brought upon the tipple and dumped, while the third is weighed—and so on through the whole train. The interruption of train-movement required for weighing (and the simultaneous dumping of a preceding car) is very small. In fact, a skillful weigh-man, operating the tipple by means of a small lever, can weigh and dump all the cars of a train in slow motion, without really stopping them at all. After the rotation of the tipple has been thus started, the remainder of its movement is automatic; it revolves completely, comes back, and cushions itself properly in its former position, without further attention.

A small tipple of this kind, operated with the small 1,000-lb. cars, dumps regularly 7 cars, and, on a test-run, has dumped 11 cars per minute. The large tipple has a regular rate of four 3-ton cars, and has dumped, on a test-run, 7 such cars per minute. In fact, the capacity of the tipple is practically limited only by the capacity of the shaking-screen placed below it to receive the coal.

The tipple is simple and (consisting, as it does, of riveted work) very solid. The motor car can run through the tipple as fast as 20 miles per hr. without injury to anything. It needs no attendance; does not get out of order; requires a single track only, thereby saving the cost of wooden trestles, etc., and is, on

the whole, cheaper in construction and operation than any other automatic tipple.

The details of construction, coupling, arresting and holding of cars, and tilting mechanism for the tipple are simple, though, of course, important with reference to the supreme need, in such an operation, of solidity, stability, safety and certainty of automatic operation. Mine-managers cannot afford to use machinery of this kind, however ingenious, which is liable to break down.

Screening and Washing.

As already remarked, the most advantageous limit for lump-coal has been found to be that of a 2 in. round hole in the screen. The screens upon which the coal is dumped have, therefore, holes of this size. The lump-coal thus produced sells at an average price of $2.10 per ton.

Two systems of disposing of the smaller coal passing these screens are now in use:

1. Under the first system, used at Mine No. 1, this coal is run over a screen having 0.75-in. round holes; the over-size is sold as "nut" at the average price of $1.35 per ton; and the under-size, after washing in a simple trough-washer, is sold at 50c. per ton. (This washer is very wasteful. It is estimated that 600 tons of coal per month go down stream from it. But this estimate is probably too high.)

2. Under the second system, used at Mine No. 2, all the small coal (under 2-in. diameter) is elevated and washed in jigs. The jigging is extremely simple, because there is no dirt sticking to the coal. The seam has no partings, and is absolutely clean coal from top to bottom, so that, apart from the usual slate broken from the top, the only foreign matter is fine, hard fire-clay, separated from the floor by the picks of the under-cutting machine. This fire-clay, however small in amount, is extremely objectionable, and, unless removed by washing, ruins the coal. The total weight of all impurities thus removed is about equal to the weight of the moisture in the cleaned product, so that the jigs practically furnish, by weight, as much salable coal as they receive of crude material. This product is sold without further sizing at $1.10 per ton.

The two systems may be compared as follows: For every 100 tons of coal mined, Mine No. 1 produces 53 tons of lump,

27 tons of nut, 10 tons of slack, and 10 tons is washed away by the trough-washer. At the values given above, this would net \$152.80, or \$1.528 per ton. In Mine No. 2, 65 tons of lump would be produced, and 35 tons of washed, nut and slack, netting the company \$175.00, or \$1.75 per ton.

Against the second system, must be charged a slight increase in the cost of washing, due to the difference between operation, maintenance, etc., of the jig and trough-washer plants. This is a very small item and, from the data available, cannot be figured, one man being required to operate the washer in either case, the sole difference being in power and maintenance, the item of water-supply being decidedly in favor of the jig system. After making such allowances, the No. 2 system is markedly preferable, because of the utilization of fuel, which would otherwise be lost forever. We have found the horizontal shaking-screen the most suitable for our purpose.

Summary.

In the foregoing outline, the nature and extent of the economies effected as the result of our experiments have been briefly stated. The total improvement has been estimated in an official report, based upon actual practice, and dated about a year ago—since which time changes in the market prices of coals, the labor-situation and the conditions of railway-transportation have largely increased the advantages of the new system.

The report referred to is a comparison between the old system of small cars, room-switches, mule-haulage, sizing, washing, etc., employed in Colliery No. 1, and the improved system of buggies, large cars, and electric haulage, sizing, jigging, etc., as perfected and practiced in No. 2. It shows that, under the new system, the whole plant is more cheaply constructed and maintained; that there is a greatly increased storage-capacity in mine-cars (an important item, in view of the present scanty and irregular supply of railroad-cars in this region, as everywhere else in the United States); that contractors and their workmen earn more money, while the daily output of coal per man is increased; that for a tonnage of 250 tons per day the number of workmen, outside of those employed by the contractors, is reduced from 46 to 16, a saving of \$41.35 per

day; that there is an additional saving of $27.85 per day in mule-feed, switches, oil, laying of pipes and tracks, etc.; that the aggregate saving in these items of current running expense amounts to 27.68c. per ton of coal mined, while the increase in the receipts from sales averages 22.20c. per ton, making a total of 49.88c. per ton, as the net gain of the improved system as a whole.

It is scarcely necessary to say that this result, effected in the production of a material, the selling-price of which per ton ranges from $2.10 down to $0.50, and has averaged under the old system about $1.50, and, under the new, about $1.75, is important enough to make all the difference between business success and failure, and therefore justifies the costly experiments and the radical innovations involved in the adoption of the improved system above described.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Gold Dredging in the Urals, with Notes on Dredging in Siberia.

BY WILLIAM H. SHOCKLEY, NEW YORK, N. Y.

(Bethlehem Meeting, February, 1906.)

[SECRETARY'S NOTE.—The following notes, arranged and edited in this office, but not yet revised by the author, were placed at my disposal with much modest hesitation (due to their incomplete and fragmentary character), upon my earnest request, and my argument that such recent and trustworthy data concerning a new and important mining industry ought not to be withheld from our *Transactions*, simply because they are not sufficient to constitute a complete academic treatise on the subject. This argument is recommended to the attention of many other members, who are waiting for the opportunity to contribute something "monumental" to our *Transactions*. In a number of instances, death has nullified this ambition, and the intended "monumental" contribution has turned out to be an obituary notice by the Secretary, instead of a valuable record of the professional experience thus hopelessly lost to the world.—R. W. R.]

The official publications of the the Russian Government give fairly complete statistics of the dredges operated in the Empire; and in a recent English bluebook, Mr. Cook's report on Siberian Trade presents a brief account of dredging in Siberia. The data in Table I. (not given by Mr. Cook) have been taken from the *Gold Mining Messenger* (Russian) for July, 1905. These interesting statistics, though incomplete, show that the Yenisei dredges are working on poor ground and yield small returns. According to report, but few yield a profit exceeding 10 per cent. per annum on the capital invested.

In the summers of 1904 and 1905, I traveled in the Urals as far north as lat. 61° N., long. 61° E., on the the Lozva river, a part of the vast system of the Ob river. This clear-water stream starts from the summits of the Urals at an altitude of 4,000 ft., and flows through a flat country, densely wooded with larch, spruce, pine, fir, birch and poplar. The river is full of fish, and is navigable for good-sized steamers as far as Ivdell. Winter lasts from early November to late April, the temperature ranging from -60° F. to a summer maximum of 90° F. The rainfall is 20 in. The climate is healthy, although mosquitoes,

TABLE I.—*Data of Gold Dredging in the Urals.*

	Size of Buckets, Cu. Ft.	Speed Buckets, Per Min.	Nominal Capacity Per 24 hr.		Period of Operation, 1904.				Chief Cause of Shut-Down.	Total Quantity Worked.		Average Quantity Per 24 hr.		Value of Gravel.[e]		Production of Gold.[f]			Value of Gold Produced.	Total Expense.	Profit or Loss.
			Cubic[c] Sagenes	Cubic Yards.	Began.	Stopped.	Days Worked	Days Idle.		Cubic Sagenes.[c]	Cubic Yards.	Cubic[c] Sagenes	Cubic Yards	Doll[d] Per 100 Poods	Cents Per cu.yd	Poods	Zolotniks.	Doll.	Rubles[g]	Rubles[g]	Rubles[g]
Dredges, Valley Yenisei River.[a]	4.5	11	90	1,143.0	Apr. 22	Oct. 25	157	30	Trommel	15,050	193,135	96	1,219.2	6.8	$0.163	3	16	...	...	...	...
	5.0	11	100	1,270.0	Apr. 24	Oct. 27	144	12	Small	13,460	170,942	93	1,181.1	7.7	0.186	3	14	56	...	...	...
	4.5	10	75	852.0	Apr. 29	Oct. 29	177	7	Small	17,092	217,068	96	1,219.2	3.3	0.079	1	33	50			
	4.5	10	85	1,079.5	Apr. 21	Oct. 29	187	4	Small	17,500	222,250	93	1,181.1	3.6	0.086	2	2	64	138,142	123,188	+14,954
	6.0	11	105	1,333.5	Apr. 25	Oct. 29	181	6	Tumblers	23,957	304,254	132	1,676.4	4.6	0.110	3	22	37			
	5.0	8	110	1,524.0	May 23	Oct. 7	132	6	...	6,227	79,083	47	596.9	7.5	0.180	1	21	52	27,800	...	...
	5.0	11	100	1,270.0	May 25	Oct. 29	147	10	...	10,175	129,223	69	876.3	7.0	0.168	2	13	13	42,500	33,520	+9,000
	5.0	11	120	1,524.0	May 9	Oct. 29	156	17	...	12,935	164,275	88	1,054.1	5.2	0.125	2	8	45	40,565	50,765	—10,200
					Location of Dredge.																
Other Dredges.[b]	3.0	20	110	1.397.0	Ivdell.		...	...	...	...	...	100	1,270 0	10.0	0.240	...	...	...	90,000	25,000	+65,000
	4.5	8	...	...	Bogoslovsk.		112	95	...	6,825	86,678	34	431.8	7.8	0.187	4	25	...	...	...	...
	4.5	8	...	...	Lobva River.		...	...	...	...	...	60	762.0	6.5	0.150	1	24	69	30,125	20,803	+ 9,322

[a] From the *Gold Mining Messenger* (Russian), July, 1905. [b] From personal notes of W. H. Shockley. [c] One cubic sagene equals 12.7 cubic yards. [d] One doll per 100 poods equals 2.4 c. per cubic yard. [e] Other dredges in the Yenisei region gave a yield of from 3.8 to 11.8 doll per 100 poods ($0.09 to $0.28). [f]. A pood of pure gold is worth 21,156 rubles; a pood of alluvial gold in the Urals is worth 19,000 to 20,000 rubles, say $9,500. [g]. One ruble equals 51.5 c. U. S. currency.

black flies and gnats are pests in summer. Winter is the season for travel, prospecting and forestry. The population, chiefly of Finnish type, is scanty and independent. Tartars, from Kazan on the Volga, do much of the hard work in the mines. There is but little agriculture; the people being supported by fishing, hunting and mining.

The route to this section is from St. Petersburg via the lately-finished railway to Viatka and Perm, to Goroblagodatskaia ("the blessed mountain"), thence by branch-railway to Bogoslovsk, and by post-horses to Ivdell; north of this, the travel is by boats in summer, and by reindeer-sledges in winter.

Ten dredges are now operated in this region, and eight more are under construction. It was thought that all would be operated in the summer of 1906; but political troubles have doubtless interfered with this programme.

The southernmost dredges, near Nijni Tura, belong to the Société Industrielle du Platine, of Paris, which employs 8,000 men, and practically controls the platinum-industry. There are two of these dredges, both formerly used on the Suez Canal. The first removes 12 ft. of top soil, which is not washed; and the second digs and washes the remaining 5 ft., which is pay-dirt. The expense of this double working is reported to be 25c. per cu. yd. Two Bucyrus dredges are being built for this company by the Putiloff Works of St. Petersburg.

The San Galli Co. works a Bucyrus dredge in a swift stream flowing by slate cliffs, a few miles north of Nijni Tura. This stream, at first considered virgin ground, was afterwards found to have been worked in the past. The dredge excavates 1,200 cu. yd. per day, and, during the season, should take out 60,000 rubles' worth of gold at a cost of 30,000 rubles. The bed-rock is of hard slate; and boulders up to 300 lb. in weight are of common occurrence. Two iron pans, 15 ft. in diameter, with revolving arms, are provided to deal with the clay. While one pan is filled by the buckets, the outlet-valves of the other are closed, and the retained material is stirred until the clay is disintegrated and the rocks cleaned. In this manner, the dredging-operation is uninterrupted. A gate, shutting off the feed to the pans, and an iron chute, directing the dredged material directly to the tailings-belt, were provided; but, unfortunately, the water carried up by the buckets washed the dirt to the

lower end of the tailings-belt and prevented its working. In order to overcome this difficulty, it has been found necessary to treat the gravel in the pans, even though no clay be present.

Two dredges of the New Zealand type, made at Neviansk, near Ekaterinburg, are on the Lobva river near Bogoslovsk. One of these, with an iron pontoon, costing 90,000 rubles at the maker's works, when first put in the river, was hung up on a rock and nearly lost. The other, with a wooden pontoon, cost 50,000 rubles at the works. The total expenses, on account of the latter dredge, to August 1, 1905, are given in Table II.

TABLE II.—*Expense Account of Dredge at Lobva River.*

	Rubles.		Rubles.
General,	7,578.92	Wood,	609.02
Notary and legal,	1,400.80	Buildings,	4,144.68
Pontoon,	6,153.85	Materials,	6,672.94
Excavation for pontoon,	1,055.68	Payment for dredge,	50,100.00
Prospecting,	1,395.20		84,461.59
Peasant proprietors,	343.36	Working expense for two months,	4,131.59
Salaries,	2,302,66		
Setting-up,	2,704.48	Total,	88,593.18

This dredge was built in the winter of 1904-5 in a pit excavated on the river-bank. During the construction, chips, shavings, hay, and manure from the teams employed in hauling the dirt, covered the ice in the pit, and, by protecting it from the sun's rays, retarded the spring thawing a full month. During this delay, the river fell 10 ft. lower than the dredge. Instead of digging a diagonal canal to the river, the pit was deepened vertically and the tailings were removed by teams. Another month was occupied in this work, giving a total loss of two months, due to bad management.

At Bogoslovsk, 1,663 prospecting shafts, of an average depth of 1.75 sagenes (12.25 ft.), cost, on the average, 17.03 rubles ($8.50), equivalent to $0.70 per foot. In Alaska, similar shafts cost from $3.50 to $8 per foot.

Neither of the two dredges on the Lobva river yielded any profit during 1905, although the gravel carried 16c. per cu. yard. In 1904, the Bogoslovsk estate began work with a Neviansk dredge of the New Zealand type on the bed and banks of a small sluggish stream, having a total width of 200 ft. The gravel is soft for a depth of 14 ft., with 5-ft. pay-dirt. This

Fig. 1.—Town of Ivdell, Northern Urals.

Fig. 2.—"Bucyrus" Dredge on Ivdell River, August, 1905.

FIG. 3.—"STARATELI" HAND-DREDGING ON THE IVDELL RIVER, SEPTEMBER, 1905.

FIG. 4.—HAND-DREDGING ON IVDELL RIVER, SEPTEMBER, 1905.

company is building two similar dredges of the New Zealand type, somewhat improved by a study of illustrated catalogues and of the Bucyrus dredges working in the region. A Neviansk dredge on the Sosva river, 60 miles north of Bogoslovsk, stuck on a rock at the beginning of the season, and in three months produced only 1.5 lb. of gold.

The most successful dredging in the Urals is at Ivdell, a pretty hamlet 90 miles north of Bogoslovsk; a photographic view of this town is shown in Fig. 1. A Bucyrus dredge, built by the Putiloff works under the supervision of H. L. Lawson, an American dredge-master, was operated almost without a stop during its first season in 1905. Fig. 2 is a photograph of this dredge, which shows the steep banks of the Ivdell river in the background. It has dredged nearly a mile of the Ivdell river, a swift stream 200 ft. wide, flowing through a limestone formation. The amount excavated daily is estimated at 1,500 cu. yards. The cost of the dredge complete, including a Keystone drill and some prospecting-work, was 140,000 rubles; and the profit for 1905 is estimated at 65,000 rubles. A duplicate dredge, estimated to cost 100,000 rubles, is under construction. On all these dredges, tables are used to save the gold; the Ivdell dredge has shaking screens; the others, revolving trommels.

Figs. 3 and 4 illustrate the method of dredging by hand on the Ivdell river, September, 1905.

TABLE II.—*Cost of Operating the Dredge at Ivdell, in Rubles, Worth Each About* 50c. *U. S. Money.*

	Per Month.	Total.
3 pilots,	@ 75	225
3 machinists,	@ 75	225
3 firemen,	@ 30	90
3 oilers,	@ 40	120
2 woodmen,	@ 35	70
2 clean-up men,	@ 25	50
1 blacksmith,	@ 40	40
1 goldwasher,	@ 30	30
1 dredge-master (American),	@ 360	360
Wood,	@ 300	300
	Total,	1,500

The maximum expense per month, including repairs and all materials used, is estimated at 3,000 rubles, or $1,500.

TABLE III.—*Cost of Supplies at Ivdell.*

	United States Currency.		United States Currency.
Butter, per lb.,	$0.20	Meat, moose, per lb.,	$0.03
Fish, fresh, per lb.,	0.06	Meat, reindeer, per lb.,	0.05
Fish, salt, per lb.,	0.03	Potatoes, per lb.,	0.004
Flour, per lb.,	0.013	Sable skins, each,	7.50
Hay, per ton,	5.50	Sugar, per lb.,	0.10
Labor, ordinary, per day,	$0.30 to 50	Wood, per cord,	0.50
Lumber, per 1,000 ft.	7.50	Reindeer, alive, per head,	7.50
Meat, beef, per lb.,	0.05		

From my observations, and from conversations with H. L. Lawson, dredge-master at Ivdell—an American with 10 years' experience in Montana and Idaho—I conclude that, for successful dredging in the Urals, the following conditions should be assured:

1. The work should be under charge of an American or New Zealand dredge-master, who has had experience in cold countries. This is a vital point. The Russian engineers, though well-educated and intelligent, are poor managers.

2. Extensive prospecting is needed, and can best be done in winter, by sinking shafts on the Siberian system, *i. e.*, allowing the water to freeze, sinking a short distance, waiting for the water to freeze again, and eventually reaching the bed of the river, even through running water (This method, however, sometimes fails in the Urals, owing to unfavorable weather, or the presence of warm springs). Hand-dredges, worked by parties of six men (or often by three men and three women), and washing a few yards daily, are useful for prospecting river-beds. A Keystone drill should be used in the river-banks by every dredging-company. In most of the Ural rivers, the chief values seem to be in the streams; the banks paying very little.

3. A small dredge, run by steam or horse-power, and costing, complete, not more than $5,000, would be of value on these rivers.

4. Dredges should be built on the bank and launched, in order to avoid the expense of a pit. Wooden pontoons should be used.

5. If prospecting-work shows that there is much clay in the gravel, the enterprise had best be abandoned, because no

method of dredging has yet been devised that will handle successfully material of this character.

6. The gold, which is uniformly coarse, should be saved in iron-lined, wooden sluices, and not on tables. These sluices should be 120 ft. long, like some used in Montana dredging. The question of sluices versus tables is still in dispute; but the advantages of the former seem to me decisive. Nuggets which pass over ordinary tables can be saved in sluices. Repairs to sluices are trifling compared with the expense of keeping up the belts of tables. Moreover, in a cold climate, a sluice can be operated for a number of days longer than a belt or a bucket-elevator. The water flowing in a large stream does not freeze so readily; and hence it is not necessary to shut down when the first cold snap comes.

7. Grizzlies should be provided to remove the large stones, which should first be washed.

8. Two boilers are needed, steam being kept in one while the other is being cleaned. In this way less time is lost; and the extra boiler is also useful for other purposes. All driving-shafts should be bored longitudinally, so as to allow an obstinate wheel or gear to be loosened for removal by heating, the shaft being kept cool by a stream of water flowing through it.

9. For swift rivers, buckets of 3 cu. ft. capacity are large enough. These should be closely set, and should excavate from 1,500 to 2,000 cu. yd. daily. For a dredge of this capacity, the following engines are advised: 60-h.p. for digging; 60-h.p. for 14-in. pump; 15-h.p. for swinging; 15-h.p. for trommel; 15-h.p. for elevating tailings (not needed if sluice is used); and 20-h.p. for electric light.

10. For swift streams, spuds are preferable to head-lines for holding the dredge in place. The top tumbler-shaft should be adjustable.

The mineral resources of the Urals are very great, and there is an immense field for dredging in the Russian Empire. When the present political troubles have passed away, the industry will exhibit a rapid development.

The Russian laborer is very good, considering his wage; and the officials, though sometimes troublesome, yield to tact and other influences.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Effect of Low Temperature on the Recovery of Steel from Overstrain.

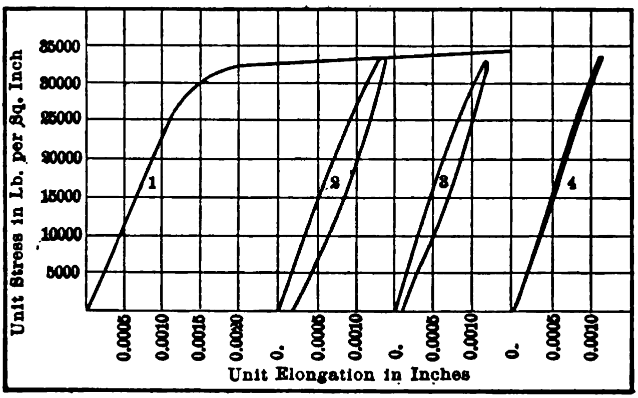
BY E. J. MCCAUSTLAND, ITHACA, N. Y.

(London Meeting, July, 1906.)

[EDITOR'S NOTE.—Supplementary diagrammatic charts, showing the results of the heat-treatment of Specimens Nos. 1 to 12, to accompany the paper by Mr. McCaustland, which was published in *Bi-Monthly Bulletin*, No. 9, May, 1906, pp. 447 to 466. Several of the blocks used for these illustrations were lost in transit, and could not be replaced in time for publication in the May *Bulletin*. The paper to be published in the *Transactions*, Vol. XXXVII., will contain both text and illustrations.—J. S.]

Specimen 1, *Extra Soft Steel* (see p. 456, 457).

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Elastic limit, 27,500 lb. per sq. in. Permanent set in 8 in., 0.04 in.



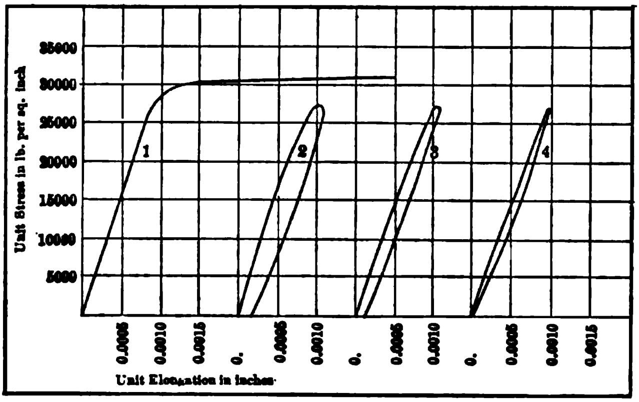
1.—Stress-deformation curve.

Cyclical Loadings.

2.—15 min. after overstrain.
3.—19 hr. after overstrain.
4.—68 hr. after overstrain.

Specimen 2, *Extra Soft Steel* (see p. 456, 457).

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Elastic limit, 28,000 lb. per sq. in. Permanent set in 8 in., 0.03 in.



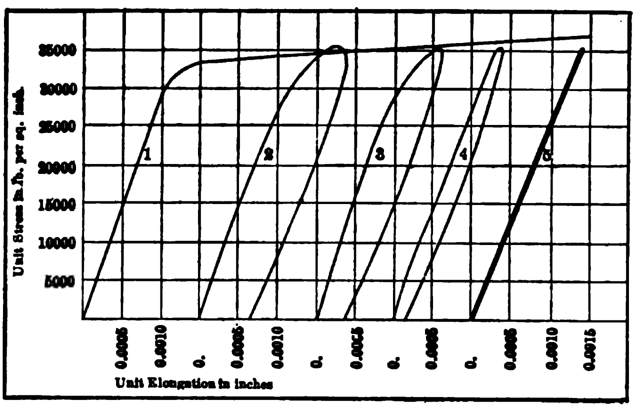
1.—Stress-deformation curve.

Cyclical Loadings.

2.—15 min. after overstrain.
3.—18 hr. after overstrain.
4.—69 hr. after overstrain.

Specimen 3, *Mild Steel* (see p. 456, 458).

Round rod, 0.63 in. diam. Area, 0.312 sq. in. Elastic limit, 32,000 lb. per sq. in. Permanent set in 8 in., 0.06 in.



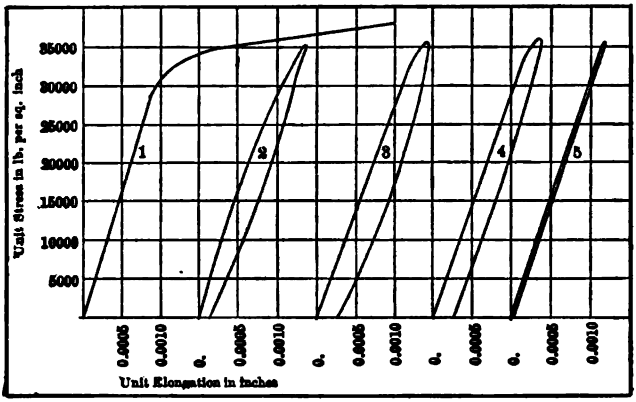
1.—Stress-deformation curve.

Cyclical Loadings.

2.—15 min. after overstrain.
3.—25 hr. after overstrain.
4.—48 hr. after overstrain.
5.—434 hr. after overstrain.

Specimen 4, *Mild Steel* (see p. 456, 458).

Round rod, 0.63 in. diam. Area, 0.312 sq. in. Elastic limit, 32,000 lb. per sq. in. Permanent set in 8 in., 0.04 in.



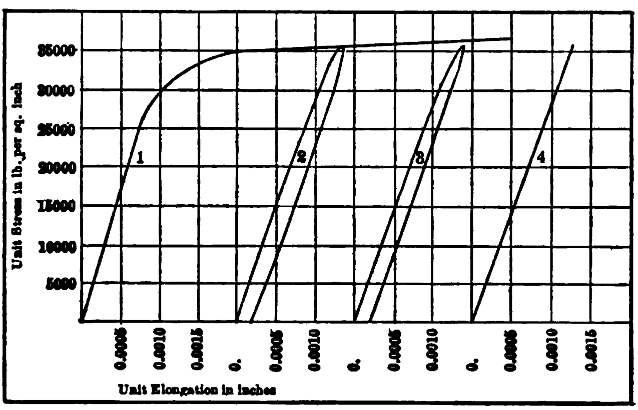
1.—Stress-deformation curve.

Cyclical Loadings.

2.—15 min. after overstrain.
3.—23 hr. after overstrain.
4.—47 hr. after overstrain.
5.—359 hr. after overstrain.

Specimen 5, *Extra Soft Steel* (see p. 459, 460).

Section, $\frac{5}{8}$ in. by 2 in. Area, 1.25 sq. in. Elastic limit, 28,000 lb. per sq. in. Permanent set in 8 in., 0.05 in.



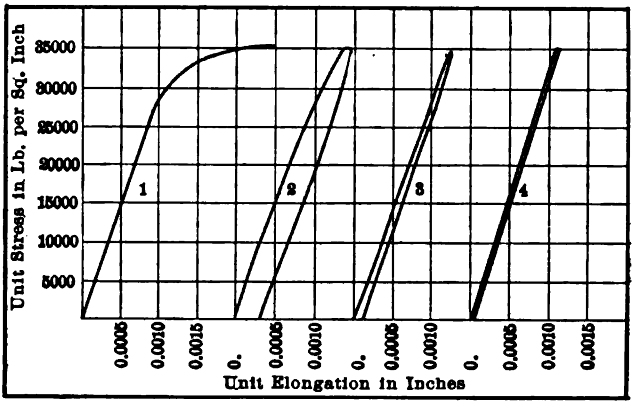
1.—Stress-deformation curve.

Cyclical Loadings.

2.—15 min. after overstrain.
3.—2 hr. after overstrain and 15 min. after steam-bath of 45 min.
4.—25 hr. after overstrain and 23 hr. after steam-bath.

Specimen 6, *Extra Soft Steel* (see p. 459, 460).

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Elastic limit, 28,000 lb. per sq. in. Permanent set in 8 in., 0.05 in.



1.—Stress-deformation curve.

Cyclical Loadings.

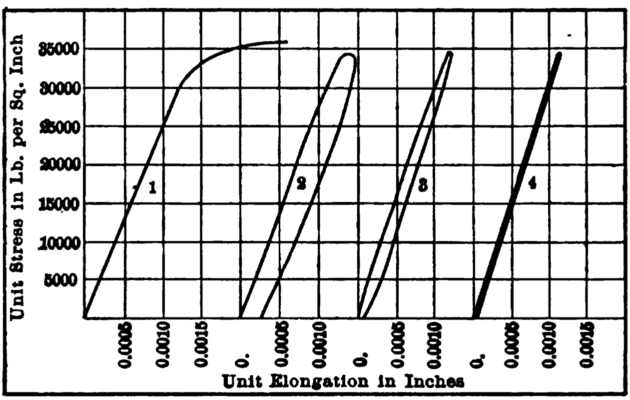
2.—15 min. after overstrain.

3.—3 hr. after overstrain and 1 hr. after steam-bath of 45 min.

4.—26 hr. after overstrain and 24 hr. after steam-bath.

Specimen 7, *Mild Steel* (see p. 459, 461).

Round rod, 0.63 in. diam. Area, 0.312 sq. in. Elastic limit, 30,000 lb. per sq. in. Permanent set in 8 in., 0.013 in.



1.—Stress-deformation curve.

Cyclical Loadings.

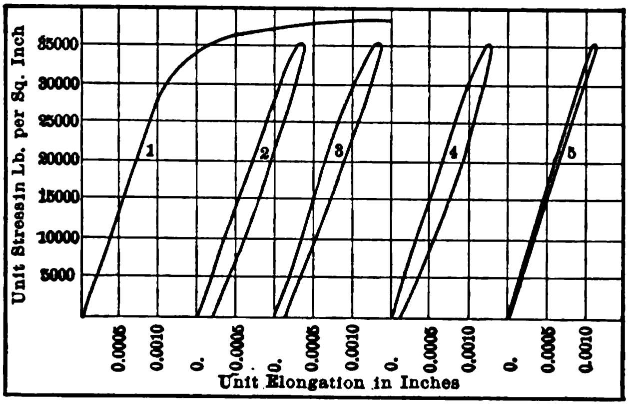
2.—15 min. after overstrain.

3.—2 hr. after overstrain and 30 min. after steam-bath of 45 min.

4.—24 hr. after overstrain and 22 hr. after steam-bath.

Specimen 8, *Mild Steel* (see p. 459, 461).

Round rod, 0.63 in. diam. Area, 0.312 sq. in. Elastic limit, 30,000 lb. per sq. in. Permanent set in 8 in., 0.015 in.



1.—Stress-deformation curve.

Cyclical Loadings.

2.—15 min. after overstrain.

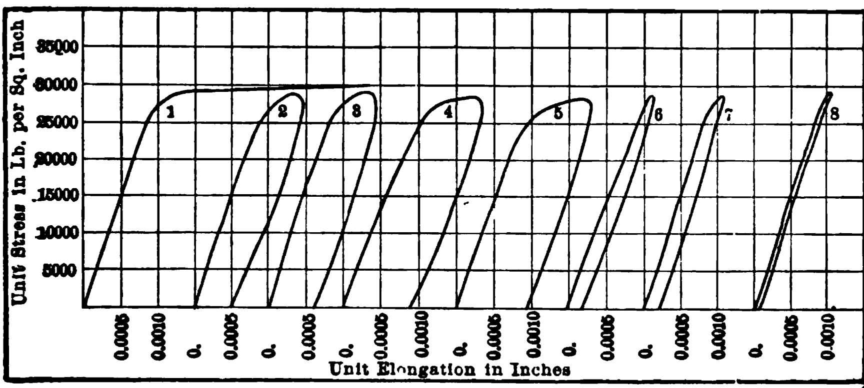
3.—24 hr. after overstrain and 22 hr. after steam-bath of 45 min.

4.—49 hr. after overstrain and 47 hr. after steam-bath.

5.—119 hr. after overstrain and 117 hr. after steam-bath.

Specimen 9, *Extra Soft Steel* (see p. 462, 463).

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Elastic limit, 27,000 lb. per sq. in. Permanent set in 8 in., 0.024 in.



1.—Stress-deformation curve.

Cyclical Loadings.

2.—15 min. after overstrain.

3.—48 hr. after overstrain, 47 hr. at freezing-temperature.

4.—2,092 hr. after overstrain, 2,091 hr. at freezing-temperature.

5.—2,136 hr. after overstrain, 2,112 hr. at freezing, 24 hr. at moderate temperature.

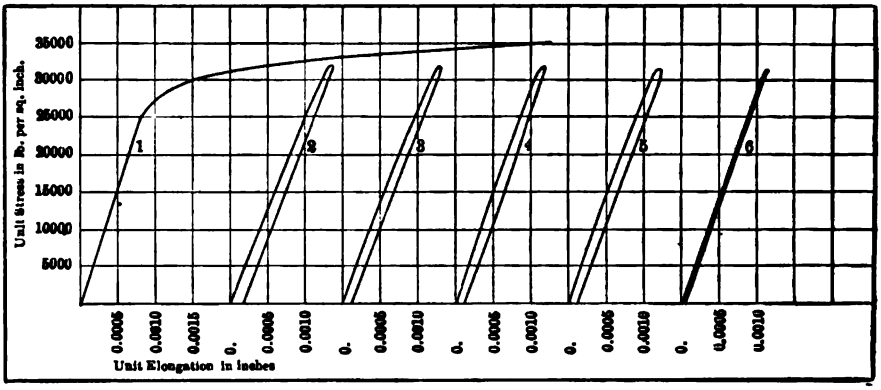
6.—2,183 hr. after overstrain, 2,112 hr. at freezing, 71 hr. at moderate.

7.—2,231 hr. after overstrain, 2,112 hr. at freezing, 119 hr. at moderate.

8.—2,254 hr. after overstrain, 2,112 hr. at freezing, 142 hr. at moderate.

Specimen 10, *Extra Soft Steel* (see p. 463).

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Elastic limit, 27,500 lb. per sq. in. Permanent set in 8 in., 0.046 in.



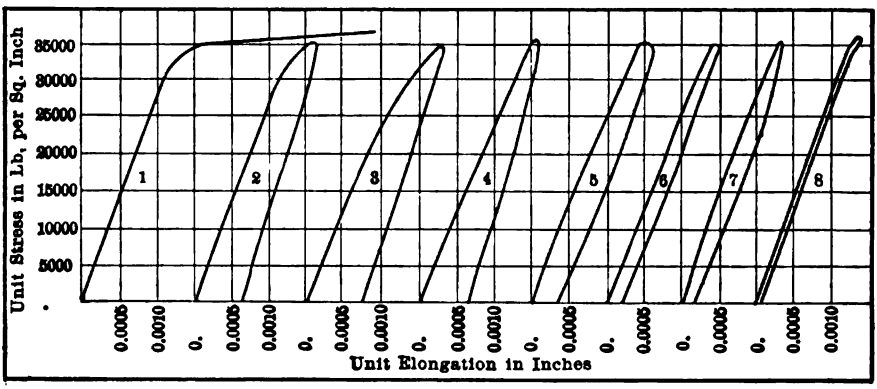
•1.—Stress-deformation curve.

Cyclical Loadings.

2.—24 hr. after overstrain, 23 hr. at freezing-temperature.
3.—168 hr. after overstrain, 167 hr. at freezing-temperature.
4.—361 hr. after overstrain, 360 hr. at freezing-temperature.
5.—4,728 hr. after overstrain, 4,727 hr. at freezing-temperature.
6.—4,848 hr. after overstrain, 4,727 hr. at freezing, 120 hr. at moderate temp.

Specimen 11, *Mild Steel* (see p. 464, 465).

Round rod, 0.63 in. diam. Area, 0.312 sq. in. Elastic limit, 30,000 lb. per sq. in. Permanent set in 8 in., 0.02 in.



1.—Stress-deformation curve.

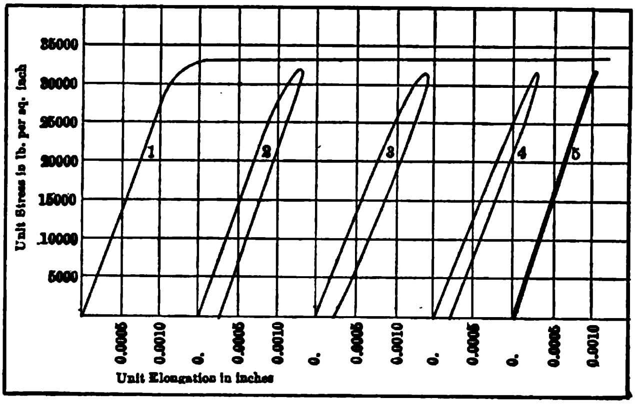
Cyclical Loadings.

2.—15 min. after overstrain.
3.—73 hr. after overstrain, 72 hr. at freezing-temperature.
4.—2,708 hr. after overstrain, 2,707 hr. at freezing-temperature.
5.—2,732 hr. after overstrain, 2,708 hr. at freezing, 24 hr.
6.—2,754 hr. after overstrain, 2,708 hr. at freezing, 46 hr.
7.—2,778 hr. after overstrain. 2,708 hr. at freezing, 70 hr.
8.—2,801 hr. after overstrain, 2,708 hr. at freezing, 93 hr.

} At moderate temperature after steam-bath.

Specimen 12, *Extra Soft Steel* (see p. 464, 466).

Section, ⅝ in. by 2 in. Area, 1.25 sq. in. Elastic limit, 28,500 lb. per sq. in. Permanent set in 8 in., 0.047 in.



1.—Stress-deformation curve.

Cyclical Loadings.

2.—15 min. after overstrain.

3.—71 hr. after overstrain, 70 hr. at freezing-temperature.

4.—2,112 hr. after overstrain, 2,111 hr. at freezing-temperature.

5.—2,135 hr. after overstrain, 2,111 hr. at freezing-temperature, and 24 hr. after steam-bath.

AMERICAN INSTITUTE OF MINING ENGINEERS

ORGANIZED 1871

INCORPORATED 1905

No. 11. SEPTEMBER. 1906.

Bi-Monthly Bulletin

OF THE

American Institute of Mining Engineers.

PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS

At S.-W. Cor. Seventh and Cherry Sts.

PHILADELPHIA, PA.

EDITORIAL OFFICE AT 99 JOHN STREET, NEW YORK, N. Y.

Entered December 6, 1904, at Philadelphia, Pa., as second-class matter under Act of Congress of July 16, 1894.

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This section contains announcements of general interest to the members of the Institute, but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions*.

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Howe, H. M.									V	V						M
Hunt, A. E.																
Hunt, Robert W.						M	M	M					P			
Hunt, T. Sterry			M	M	M		P									
Johnson, J. E.																M
Jones, Clemens C.																
Kemp, J. F.																
Kennedy, J.																
Kent, Joseph C.				V	V											
Kent, William																
Kerr, W. C.													V			
Keyes, W. S.										M	M	M		V		
Kimball, J. P.											V	V				

ITS ORGANIZATION IN 1871 TO 1906.

Secretary; T, Treasurer; t, Assistant Treasurer; D, Director; C, Councilor; e, Assistant Editor.

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For the year ending February, 1907.

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(Term expires February, 1909.)

Consulting Attorneys, Blair & Rudd, New York, N. Y.

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* SECRETARY'S NOTE.—The Council is the professional body, having charge of the election of members, the holding of meetings (except business meetings), and the publication of papers, proceedings, etc. The Board of Directors is the body legally responsible for the business management of the Corporation, and is therefore, for convenience, composed of members residing in New York.

BI-MONTHLY BULLETIN.

For the convenience of persons who desire to file, or otherwise use separately, the technical papers in Section II. of the Bulletin, each of these papers has been paged and wired by itself; the whole collection being held together by a single, heavy wire, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

All communications concerning the contents of this Bulletin should be addressed to Dr. Joseph Struthers, Assistant Secretary and Editor, 99 John St., New York City (P. O. Box 223; Telephone number 5477 John).

UNITED ENGINEERING SOCIETY BUILDING.

Descriptions of the progress of the work on the Engineering Societies Building have been given in the *Bi-Monthly Bulletins* for March, May and July of this year. Since July, the date of the previous issue, the completion of the work on the new home for the Engineering Societies has been both rapid and satisfactory.

The following report of the present condition of the building, July 10th, has been received from Mr. Henry G. Morse, associate architect with Mr. Herbert D. Hale:—

1. *Plastering:* This branch of the work has been rapidly carried on, and but little remains to be done. The plastering of the Library (floors 13th and 14th) is nearly finished; that of the 12th to 6th floors, inclusive, is complete, and work in the Auditorium (3d and 4th floors) has been started, which leaves only the 2d (a small mezzanine) and the 1st floors yet untouched.

2. *Trim:* The trim has been started on the doors of all office-floors. Owing to the very small amount of wood-work in the building, the trim is a very small factor.

3. *Marble-Work:* The marble-work for the corridors is practically finished on all office-floors, and the terrazzo-work has been started.

4. *Elevators:* The freight-elevator is running in good condition, and the two passenger-elevators are practically installed.

5. *Iron-Work:* All the ornamental iron-work is in the building and set up, with the exception of a few railings, doors, etc., which are to be put in at the last.

6. *Machinery:* The boilers and practically all the machinery in the basement are fully installed, and it is expected that heat will be available for drying the building by the first day of October.

7. *Windows:* All the windows are in, and the exterior is being cleaned.

In general, the work is moving very rapidly. The sub-contractors have material well in hand, and everything is propitious for the early completion of the building.

Contracts for seating in the lecture-rooms and auditoriums, for carpets, shades, electric-light fixtures, miscellaneous furniture, etc., have been given out, and early deliveries are promised.

By October, the condition of the interior of the building will be very materially changed, and during November and December there will remain merely the putting in of a few fittings, finishing, painting, etc.,—all matters of comparatively minor import.

THEODORE DWIGHT,
Engineering Building Committee.

LIBRARY.

Accessions.

From June 23 to September 10, 1906.

Alaska Treadwell Gold Mining Company.

ALASKA TREADWELL GOLD MINING COMPANY. *Annual Statement*, 4th–13th. 4to.

G. W. Colles.

COLLES, G. W. *Mica and the Mica Industry.* vi, 130 p. il. pl. 8vo. Philadelphia, 1906.

[A review of this book will be given in *Bi-Monthly Bulletin*, No. 12, November, 1906.—R. W. R.]

Engineering and Mining Journal.

One hundred and fifty-two odd numbers of periodicals and mining company's reports, including 42 duplicates.

Engineers' Society of Western Pennsylvania.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA. *Membership List*, July, 1906. 8vo. Pittsburgh, 1906.

W. R. Ingalls.

INGALLS, W. R. *Notes on Metallurgical Mill-Construction.* vii, 256 p. il. pl. 8vo. New York, 1906.

[A review of this book will be given in *Bi-Monthly Bulletin*, No. 12, November, 1906.—R. W. R.]

Institution of Mining and Metallurgy.

INSTITUTION OF MINING AND METALLURGY. *Bulletin*, Nos. 21, 22. 8vo.

Iron and Steel Institute, London.

BONVILLAN, PH. *Recent Processes in Machine Moulding-Practice.* 26 p. il. 8vo.

CARPENTER, H. C. H. *Tempering- and Cutting-Tests of High-Speed Steels.* 22 p. pl. 8vo.

COLBY, A. L. *The Nodulising and Desulphurisation of Fine Iron-Ores and Pyrites-Cinder.* 16 p. pl. 8vo.

HUBERT, H. *The Design of Blast-Furnace Gas-Engine in Belgium.* 22 p. pl. 8vo.

IBBOTSON, E. C. *The Kjellin Electric Steel-Furnace.* 6 p. pl. 8vo.

Iron and Steel Institute, London (*continued*).

JOHNSON, J. E., JR. *Different Modes of Blast-Refrigeration and their Power-Requirements.* 26 p. il. pl. 8vo.

OSMOND F. and CARTAUD, G. *The Crystallography of Iron.* 47 p. il. pl. 8vo.

REINHARDT. E. *The Application of Large Gas-Engines in the German Iron and Steel Industries.* 107 p. il. pl. 8vo.

ROE, J. P. *The Development of the Roe Puddling-Process.* 32 p. il. 8vo.

SAUVEUR, A. *Constitution of Iron-Carbon Alloys.* 29 p. il. 8vo.

THOMAS, A. S. *The Influence of Silicon and Graphite on the Open-Hearth Process.* 8 p. 8vo.

WESTGATH, T. *Notes on Large Gas-Engines Built in Great Britain; and Upon Gas-Cleaning.* 8 p. 8vo.

Mining and Geological Institute of India.

MINING AND GEOLOGICAL INSTITUTE OF INDIA. *Transactions.* Vol. 1, pt. 1. 8vo. Calcutta, 1906.

Minister of Mines of British Columbia.

An Act to Make Regulations with Respect to Coal-Mines. 37 p. 4to.

——— *An Act to Encourage Coal-Mining.* 7 p.

——— *An Act Relating to Placer-Mines (as Amended in* 1898, '99 and 1901).

——— *An Act Relating to Gold and Other Minerals Excepting Coal (as Amended in* 1898, 1899, 1900, 1901 and 1902).

——— *An Act for Securing the Safety and Good Health of Workmen Engaged in or About the Metalliferous Mines in British Columbia.*

Smithsonian Institution.

SMITHSONIAN INSTITUTION, WASHINGTON—U. S. NATIONAL MUSEUM. *Contributions from the U. S. National Herbarium.* Vol. x, pt. 2. 8vo. Washington, 1905.

Society of Arts.

SOCIETY OF ARTS. *List of Members,* 1905–'06. 8vo.

John Wiley and Sons.

MILLER, A. S. *The Cyanide Process.* viii, 95 p. il. 12mo. New York, 1906.

[A review of this book will be given in *By-Monthly Bulletin,* No. 12, November, 1906.—R. W. R.]

MEMBERSHIP.

The following list comprises the names of those persons elected as Members or Associates, who duly accepted election during July and August, 1906:—

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Sydney Fawns,	London, Eng.
Donald Ferguson,	Goldfield, Nev.
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Jerome R. George,	Worcester, Mass.
Edgar M. Gleim,	Portland, Ore.
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William Howard,	El Oro, Mexico, Mex.
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Paul Johnson,	Hadley, Ketchikan P. O., Alaska.
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Henry S. Mackay,	Santa Ana, Sonora, Mex.
Wallace W. Merriam,	Estacion Terrazas, Chihuahua, Mex.

John B. Miles, ... Philadelphia, Pa.
Bradish P. Morse, ... Denver, Colo.
Bryan K. Morse, ... Cananea, Sonora, Mex.
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Paul Nicholas, ... Springfield, Mo.
John R. Pill, ... Carbon Hill, Ala.
Harry B. Price, ... Mexico City, Mex.
Harrie B. Pulsifer, ... Lebanon, N. H.
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Joseph W. Reid, ... Yellville, Ark.
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Walter F. Smith, ... Philadelphia, Pa.
Norman C. Stines, ... Carrville, Cal.
James Stirling, ... Hollywood, Cal.
Hallyburton T. Stretton, ... London, Eng.
Harold Sturges, ... Mexico City, Mex.
John M. Sully, ... Hanover, N. M.
Maurice W. Summerhayes, ... Beckenham, Kent, Eng.
Harry L. Swain, ... Mexico City, Mex.
Hubert S. Thomas, ... Wellfield, Llanelly, Eng.
James E. Thomas, ... Krugersdorp, Transvaal, So. Africa.
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Edward A. Guntly, ... Cripple Creek, Colo.
Newton W. Pilger, ... Ruby, Mont.
Frederick B. Reece, ... Kellogg, Idaho.
James C. Simpson, Jr., ... Edinburgh, Scotland.

LIFE MEMBER.

Henry G. Ferguson, ... Ishpeming, Mich.

NECROLOGY.

Date of Election.	Name.	Date of Decease.
1889.	*William A. Akers,	June 19, 1906.
1883.	**T. S. Austin,	August 23, 1906.
1892.	*E. V. Bensusan,	May —, 1906.
1899.	*Alexander W. Jolly,	———, ———.
1893.	*John G. Lanning,	July 18, 1906.
1896.	*Stanley H. Pearce,	July 10, 1906.
1898.	*Ricardo G. Ramos,	———, ———.
1886.	*George H. Robinson,	July 3, 1906.

* Member. ** Life Member.

THE INSTITUTE ABROAD.

AN UNOFFICIAL SKETCH BY R. W. RAYMOND.

It is impracticable to prepare for the present number of the *Bi-Monthly Bulletin* a detailed account of the memorable Joint Meeting of the Iron and Steel Institute and our Institute, held in London, the last week in July, and of the innumerable festivities, entertainments and excursions which accompanied and followed it, in England, Scotland, Wales and Germany. This preliminary sketch, from which all "useful particulars" have been carefully omitted, is published unofficially, as a convenient answer to the manifold inquiries of members who did not go, and who are now trying to alleviate their unavailing regret by indulging their curiosity. Perhaps they secretly hope to hear that they did not lose so very much, after all—that the affair was not all that could have been desired or dreamed; that there were serious drawbacks, shortcomings and disappointments; and that it is just as well to have stayed at home, and now to hear about it. Let them lay no such flattering unction to their souls. The month they have missed would have been the time of their lives. They will never, never know how good a time it was, or adequately repent of their folly, if they could have gone with us, and voluntarily did not go. Of course, those who would but could not, have our immeasurable pity, without blame.

I shall present here no consecutive and minute story, but only a series of general paragraphs concerning different aspects and stages of our experience.

THE WEATHER.

The proverbial good fortune of the Institute attended its visiting members and guests at every stage of the late London meeting and the numerous excursions which accompanied or followed it. Even the process of crossing the Atlantic was made delightful by smooth seas, through which the great modern transatlantic liners made their way without disagreeable

evidences of progress. This was the case, so far as I can learn, with every Institute party of pilgrims. No racks on tables; no sloppy decks; nothing worse than an occasional use of the fog-horn. Marconigrams flying to and fro between ship and shore, or bearing greetings to passengers on other ships; telegraphic news of the world bulletined daily. In short, the ocean-passage was a delight.

And we gathered in London to enjoy such unbroken fair weather as surprised the natives. Day after day of sunshine and balmy air gave to the great metropolis an additional charm. Apart from one or two passing showers, not a single detail of the London programme was marred by unfavorable skies.

And this good fortune continued for a month, covering the week in London, the week (excepting one showery day) in northern England and Scotland, the interval of a week which followed, and the final excursions in the Rhine-country and Hanover. This last period included one rainy day; but it rained while we were under cover, only to make our outdoor experiences the more refreshing.

Such plans as were made for our entertainment in England, Scotland, Wales and Germany are always largely dependent upon the weather, and the climate of that part of the world is not to be reckoned upon beforehand. It is therefore matter of special congratulation that this latest Institute outing became, through the blessing of Heaven upon the arrangements of Earth, all that our generous hosts had hoped to make it.

THE SESSIONS.

Long before the day of meeting, it had become evident that the technical sessions provided for would give no adequate opportunity for the presentation and discussion of papers. To the "joint meeting," the Iron and Steel Institute furnished a considerable list of important contributions; and our Institute presented a still larger number, appropriate to the occasion. The President of each society read a Presidential address, and some time was necessarily given to formal business. The total time which the overwhelming hospitality of our British brethren had left for technical sessions permitted one session of the Iron and Steel Institute, one of our Institute, and one to be

divided between them. It may easily be inferred that little could be done in the way of reading papers. Even the little which the Secretaries had expected to do was further diminished by unpremeditated discussions, etc. The room was crowded (about 600 members of the Iron and Steel Institute being in town); and everything favored discussion, except the lack of time. The sessions were highly interesting; the subjects presented were burning questions of modern practice; and those who, like myself, lamented the impracticability of a calm and leisurely interchange of views among the eminent authorities and captains of industry who were present, must comfort themselves with the reflection that the valuable essays prepared for this meeting would not have been written without such a stimulus, and that the valuable debates which did not take place in the hall at London will take place (are, indeed, already in progress) through the more deliberate process of correspondence and publication.

The sessions were held in the stately hall of the Institution of Civil Engineers, on the walls of which hung the portraits of the past-Presidents of that illustrious society. Some of them I had seen in life; for nearly fifty years ago, I had accompanied Sir Charles Fox to a meeting of the Institution of Civil Engineers, and had met there the famous Brunel, Scott Russell, and other great men in the profession. Now their faces were on the wall—and the grandson of one of them was shaking my hand in welcome.

THE KING.

H. R. H., the Prince of Wales, was for many years an Honorary Member of the Iron and Steel Institute; and Edward, King of England, is now carried on its catalogue as "Patron." In view of the favor he had always shown to that society and its great work and purpose, the Council determined to confer upon him, this year, the Bessemer Gold Medal—which it had similarly given to Queen Victoria in 1899. The King having signified his acceptance, the ceremony took place at an audience given to a delegation of officers and past-officers of the two Institutes. On this occasion, the proceedings were perfectly informal. The King, in simple morning dress, without insignia of any kind, entered the room in which we were assembled; we were individually presented to him by President Had-

field; he shook hands with each of us, saying he was glad to see us (or words to that effect); Mr. Hadfield presented the medal, with an address of perhaps a dozen lines, comprising one or two sentences; the King replied that he was happy to receive this token from the representatives of so important an industry; and the ceremony was over. Then His Majesty asked a few cordial questions of Mr. Hadfield, who told him in reply that his society was endeavoring to return to their American visitors some of the abundant hospitality it had received on two occasions in the United States, at which the King nodded approval, intimating that he had experienced American hospitality himself, and added, "I suppose you will show them a little of this country, before you let them go home?" On being informed that we were to be taken to York, Middlesbro', Newcastle, Glasgow and Edinburgh, he expressed his satisfaction with that programme, and said, "I hope you will have a very pleasant time." A little later, remarking, "Well, gentlemen, I will bid you good afternoon," he departed as he had come, and we thereupon departed as we had come (to wit, in President Hadfield's splendid automobiles); and that was all. Nothing could have been more simple, hearty, and agreeable.

Seen thus at close quarters, King Edward appeared to be a stalwart, healthy, intelligent, and dignified and kindly gentleman; not needing to be pompous, in order to show himself great; completely at home in whatever circumstances, and instinctively able to put others similarly at ease; able to command without shouting, and to influence without either deceiving or dictating. And nothing is more striking than the absolute and universal unanimity with which all classes, denominations and parties in Great Britain hold and declare this opinion of their sovereign.

THE WEEK IN LONDON.

The multiplied and complicated details of arrangement were admirably handled by Secretary Brough, of the Iron and Steel Institute, and his unwearied assistant, Mr. Sidney. The headquarters at 28 Victoria St. were a rendezvous for members, with writing-room, post-office and intelligence-bureau attached. Everybody's choice was ascertained, recorded and provided for.

Of course, the week in London was a strenuous one. Every

hour was occupied with an invitation to some new festivity. Private dinner-parties; the brilliant reception of the Lord Mayor at the Mansion House; the great banquet at the Guild Hall; the fêtes at the Crystal Palace and at Earl's Court; excursions to Windsor, etc.; visits to sundry points of interest in and about London, and to great industrial establishments—all of which will be duly set forth hereafter in official style—crammed the days with "pleasure, amounting to fatigue!" But everybody soon discovered that he could not take in every thing, and live; so there was still a goodly company in excellent condition for the breezy and refreshing trip to Dover harbor, on Saturday.

THE NORTHERN TOUR.

The northern tour, which began on Monday, July 30, and ended at Edinburgh on Saturday evening, Aug. 4, was a series of cumulative interest and enjoyment. The general and local programmes had been so skillfully designed as to give us samples, as it were, of the various kinds of attractions which Great Britain possesses for Americans—scenery, castles, cathedrals, historic associations, antiquities, etc., as well as great works of modern engineering, industrial establishments and educational institutions. Thus we could inspect at York the mediæval and Roman remains and the Norman castle, as well as the great Minster, with its windows of unutterable glory, while a portion of the party, by an easy detour, visited the famous Caseby main colliery. While some visited this or that one of the great steelworks which line the Tees at Middlesbrough, the ladies were specially conveyed to Fountain's Abbey, and gracefully entertained there; after which, the re-united party spent a reverent and instructive hour in the cathedral of Durham. On Wednesday, three excursions started from headquarters at Newcastle-on-Tyne: one to the works on the river; one to the Hylton, Dawdon and Horden collieries; and one to Bamburgh and Alnwick castles. On Thursday, a similar division offered two alternative excursions; one to the Chesters and Borovicus camp, involving a drive of 28 miles along the old Roman wall; the other to the Elswick works, constituting the ordnance department of Sir W. G. Armstrong, Whitworth & Co., Limited. Glasgow furnished on Friday an entirely new and fascinating pleasure, in the trip upon the Clyde and through the wild High-

land scenery of the marine lochs and sounds which repeat on a larger scale the inland features of the neighboring Trossacks. And finally, Edinburgh, besides regaling us with her own beauty and charm, introduced us to Dunfermline, where we admired the splendid work of the Carnegie Trust (the sort of "Trust" to which nobody objects!), and went a bit daft oursel's over the magnificent marching, playing and dancing of the pipers of the 6th V. B. R. H. ("Black Watch") regiment. To this bare and partial outline should be added many particular features of social courtesy—banquets, lunches, receptions, addresses of welcome, music, flags and flowers—and all in an atmosphere of uninterrupted watchful care for the comfort and welfare of the party.

THE CARDIFF MEETING.

It was hardly to be expected that any of the American delegation would be drawn away from the attractions presented by the northern tour; yet there were a few who accepted the cordial invitation of the Institution of Mechanical Engineers, and attended the Cardiff meeting of that society, July 30–August 4. It was found impossible afterwards to convince these stragglers that they had not had a better time than the main party. Their chief reason for their confident opinion seemed to be that they could not possibly have had a better time than they did have in Wales—so there you are! We said the same thing in support of our view; and both sides rested—with no verdict to follow!

THE EXCURSION TO GERMANY.

The interval between August 4 and August 13 was spent by individual members and their friends as pleasure or business suggested. Some accepted the hospitality of new or old friends in England; some "motored" through England; some coached in the Trossacks; some skipped over to Holland, and approached Germany by peaceful canal-routes; some went to Windermere and some back to London for certain sights overlooked in the first mad week. But a goodly number—something over 100—(many more than had been at one time hoped for) turned up at the rendezvous, in Düsseldorf, on the 13th of August.

This supplementary visit, planned by the Society of German Ironmasters, and carried through with unqualified and brilliant success by Dr. Schroedter, the executive officer of that

body, was just what was needed to crown the experiences of our memorable month. It was a series of charming, varied, interesting and instructive reunions and excursions, exhibiting in equal measure the lovely scenery, the industrial progress and the warm hospitality of Germany. No part of the world more readily lends itself to such a proceeding than the region of the Rhine; no people know better "how to do it" than the people of that region; and we saw both land and land's folk at their very best, in those five golden days in and about beautiful Düsseldorf, along the storied, vine-clad Rhine, and through the famous Bergenland!

Only twenty-eight of us were able to take part in the supplementary visit to Hanover and the Harz, organized by Dr. Weiskopf and his associates of the Hanover special committee. If we had but known, months before, that the Prussian government, as well as private owners, would throw wide open to us the doors which not even natives have been permitted to pass—the doors of all mines, smelting-works, etc., in the classic old home of these industries—we would have managed somehow to stay abroad long enough to avail ourselves of this almost unprecedented opportunity. But it was impossible, this year, to give up one's steamer-accommodations and secure any others within a reasonable period; so we had to abide by our schedules of travel, and tear ourselves away. Those who remained longest, were happy then, and are boastful now! The rest are hoping for a future opportunity. In Hanover, as in Düsseldorf, the Ladies' Committee was congenial and cordial and dear, and "too lovely for anything"—so said our ladies, and so say we all of us!

P. S.—During the drive of August 2d along the old Roman wall, the Secretary had a perilous and somewhat spectacular fall, which ought to have broken his neck and smashed his ribs or his collar-bone. Those who saw the performance, and have been kindly anxious as to his welfare ever since, are hereby informed that the injury was chiefly a laceration of the muscles of the right shoulder, and, although at the time (and still, in lesser degree) painful, presents no alarming symptoms. In witness whereof, these lines have been written for the printer, without special agony, by the hand and arm belonging to the said shoulder!—R. W. R.

SECTION II.

TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents, pages i and ii.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

ERRATA.

Corrections to *Bi-Monthly Bulletin*, No. 9, May, 1906.

Page.	Line.	
469	Footnote	reference, for "Koninklikje" read "Koninklijke."
483	Footnote	reference, for "Weidemann's" read "Wiedermann's."
489	Footnote	reference, for "J. A. Grier" read "T. J. Grier."
490	9	for "Brittania" read "Britannia."
490	12	for "Supt. Reed" read "Supt. Read."

Corrections to *Bi-Monthly Bulletin*, No. 10, July, 1906.

Page.	Line.	
517	16	for "orogeneric" read "orogenic."
520	Table III.	for "silts" read "pits."

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Comparison of American and Foreign Rail-Specifications, With a Proposed Standard Specification to Cover American Rails Rolled for Export.

BY ALBERT LADD COLBY, NEW YORK, N. Y.

(London Meeting, July, 1906.)

TABLE OF CONTENTS.

I. INTRODUCTION.

A GLANCE through the Bibliography appended to this paper will show that the *Transactions* of this Institute contain what virtually contitutes a history of the development of the manufacture of steel rails in this country and abroad. It is, therefore, fitting that this paper, bringing one branch of this important subject down to date, should be here presented, and it is also appropriate to select this joint meeting of our Society with the Iron and Steel Institute to compare the specifications covering the rails produced in these two countries, and to propose a standard specification to govern the manufacture of American rails for export.

During the last ten years the production of Bessemer steel rails in the United States and Great Britain has amounted to 32,128,720 gross tons. Nearly 19,000,000 tons have been rolled in the past five years. The next five years will see an even larger output, owing partly to the extension of railway projects in the Orient, in South and Central America, in Mexico, and in Australia and the other British Colonies.

Of late years, the American rail-mills have so largely increased their daily output, that trade conditions have often made possible the delivery of American rails to foreign ports.

The tenders submitted by American mills, however, have always been accompanied by requests for changes in the foreign specifications, chiefly in the reduction of the amount of testing required; and it has only been natural, especially at first, that the engineer, whose specification had always been accepted without question by British mills, should interpret American tenders as an evidence that an inferior rail would be furnished

his client if the concessions were granted. After often a considerable discussion, the specifications have been modified, in some instances on the representation of independent American engineers, who make rail inspection a specialty, that the requested modifications or omissions in the requirements would not reduce the quality of the rails furnished.

Although the delivery of many tons of American rails to foreign ports have proved such to be the case, there has been no *general* acknowledgment on the part of foreign engineers, that their rail specifications must be modified if American tenders are particularly desired; instead, the necessary concessions are still a matter for individual adjustment, and, at best, the modified specification still leaves the interpretation of certain requirements in such doubt that the American mills accept orders for rails for export, with the cost due to inspection, and the possibility of a reduced output, as very uncertain factors.

The object of this paper is to clear up this matter for the best interests of all concerned. A sufficient tonnage of American rails is now in service abroad, especially in the British Colonies, to establish the fact that in no respect do they give a less satisfactory service than the product of British mills.

In the past five years much has been accomplished in both the United States and Great Britain toward the standardization of the requirements governing this large item in the tonnage of steel produced in both countries. In this paper the importance of what has been thus accomplished is duly recognized, and the requirements of the current standard and individual rail-specifications now governing the rolling of rails in each country are duly compared, so as to show that the fewer and more definite requirements which now govern the large tonnage of rails rolled for American railroads make it unnecessary, in order to obtain the same quality of product, to hamper the American methods of manufacture by the more elaborate requirements of foreign specifications.

The reason why foreign rail-specifications cannot be applied to American mills are stated plainly, and a standard rail-specification is proposed which is particularly applicable to the manufacture of rails rolled in America for export; its requirements can be met by all the American mills, so that the possibility of competition is assured; the specification includes all the checks

on the manufacturer of rails essential in the present state of the art in American mills; the requirements are definite; all ambiguous and unnecessary clauses are omitted, the idea being that a specification should be a contract strictly lived up to by both parties concerned, and having for its object the delivery, without unnecessary expense to either party, of the best possible material which can be furnished commercially for the purpose intended.

An explanation should be given as to just why the output of American rail-mills has of late years so materially increased, so as to show that this change has not reduced the quality of the product.

The gradual increase in the daily output of American rail-mills during the last decade is not due to an increase in the speed of the rail-train, prompted by a reckless desire for increased tonnage, independent of the quality, strength and finish of the product, but rather to radical improvements resulting in a much better balance between the producing and finishing-ends of the mill. In the first place, the finishing-train is used only for rolling rails, hence there are few delays due to roll changes; furthermore, the rail-train is now kept much *busier;* the bars are brought more quickly and continuously to the rail-train by the use of tables with rapidly revolving rollers; the blooming-train is seldom idle, owing to the ample heating-capacity of the modern soaking-pits and the quick stripping and handling of ignots; sufficient air-pressure is available to blow all the converters at once, if necessary; and finally, there is always an excess supply of melted pig-iron for the converters, drawn either direct from adjacent blast-furnaces, or from storage-receivers known as "mixers," which are sometimes supplemented with iron remelted in cupolas.

In times past the converting- and blooming-departments have not equalled the capacity of the rail-train, but by the improvements briefly outlined above, the lost time intervals have been materially cut down. One American rail-mill, without change in the speed of its rail-train, has thus increased its output of of rails from 1,000 to 1,800 tons per day of 24 hours.

That the maximum capacity of its finishing-train has not yet been reached, without increasing its speed, may be seen by the following calculation. With the finishing roll of 26 in. in di-

ameter, running at a speed of 95 rev. per min., its capacity, if a continuous bar was rolled, would, if cut up into 33-ft. lengths, make no less than 28,221 rails per 24. hr., or 11,087 gross tons of 80-lb. 33-ft. rails on two shifts; of course this is a theoretical output, but it proves the error of the usual criticism that the present output of American rail-mills is due to very rapid rolling.

In the following comparative discussion of the American and British specifications which govern the rails produced to-day, the requirements have been classified under the headings given in the table of contents, and this same classification has also been used in the proposed standard specification found at the end of this paper.

II. Process of Manufacture.

1. *American Specifications.*

The specifications of American railroads, as well as those known as "the Manufacturers' Specifications," and which latter govern, when no specification is submitted by the railroad, both contain a general provision, that the entire process of manufacture and testing shall be in accordance with the best current practice, and both mention certain precautions in the process with particular reference to obtaining sound rails.

2. *Foreign Specifications.*

In some foreign rail-specifications there are clauses governing the process of manufacture which should be omitted when applying the specifications to American practice. While all American makers should readily comply with a requirement that in their tender they must mention the character of the materials and the process they propose to use, their sources of supply are such that clauses worded as follows should be waived:—"Best hematite pig iron," or "No. 1 Cumberland hematite pig iron must be used." "The iron used to be made from the best English or Spanish hematite ore." "Charcoal spiegeleisen shall be used." As "direct metal" is almost entirely used in American mills, the requirement that "the iron be melted in air furnaces, or cupolas, before being run into the converters" should be omitted.

In reference to ingots, some specifications state that "each ingot shall be of ample length and weight to allow for cutting off unsound parts from each end of the rail to reduce it to the finished length;" others require that the ingot shall measure at least 10 in. at the top and 12 in. at the bottom, or at least 12 in. and 14 in. respectively. In American practice all rail-ingots are of ample size for discards; in fact, from 4 to 6 rails of the heaviest sections are rolled from each ingot. A clause such as the following is unnecessary and impracticable: "The surfaces of the ingots are to be smooth and clean; any inequalities produced by the ingot-molds must be removed by chisel. No ingots containing any defect will be accepted, and no repairs to defective ingots will be permitted." The judgment of the manufacturer as to the disposition of the ingots should govern, limiting him, however, to the requirement that he must be in accord with the best current practice. He would gain nothing by attempting to repair defective ingots; as to make such repairs he would first have to allow the ingot to become cold.

As no American rail-mill allows ingots to become cold, all rails, containing surface defects due to superficial defects in ingots, are rejected before submitting the rails to the inspector.

III. Chemical Properties.

1. *Chemical Composition.*

(*a*) *American Specifications.*—In American rail-specifications the carbon and manganese requirements increase with the weight of the section. Silicon is usually specified "not over 0.20 per cent.," which limit, with American acid-Bessemer blowing, might as well be omitted, unless silicon is purposely added, to meet special requirements. Sulphur is only occasionally specified, the upper limit being 0.075 per cent.; this is essential, as a higher sulphur-content causes red shortness, with its attendant evils, in the finish of the rail.

The limits in Table I., quoted from the manufacturer's standard specifications, govern, with but slight modifications in a few cases, by far the largest tonnage of rails delivered to-day to American railroads.

TABLE I.—*Chemistry of American Rail-Specifications.*

Weight of Rail Per Yard.	Carbon.	Manganese.	Silicon. Not Over.	Phosphorus. Not Over.
Pounds.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
50–59	0.35–0.45	0.70–1.00	0.20	0.10
60–69	0.38–0.48	0.70–1.00	0.20	0.10
70–79	0.45–0.55	0.75–1.05	0.20	0.10
80–89	0.48–0.58	0.80–1.10	0.20	0.10
90–100	0.50–0.60	0.80–1.10	0.20	0.10

In rails of 70 lb. and over, the range of carbon above specified is 5 points (0.05 per cent.) higher than standard practice in 1900.

The recent specifications of two committees of engineers recommend still higher carbons than given in Table I., lower the upper limit of manganese 0.05 per cent., and suggest a reduction of the phosphorus to 0.085 per cent.

No data have been presented proving that rails of the carbons specified in Table I., because of a content of 0.10 per cent. of phosphorus have failed or proved brittle after short service. Considerable data have been published showing that rails made under specifications allowing 0.10 per cent. of phosphorus have given excellent service. The vast tonnage of rails now in track and showing an excellent record, and which, if analyzed, would show from 0.090 to 0.110 per cent. of phosphorus, weakens a plea for a reduction in the present guaranteed phosphorus of steel rails.

To obtain a harder steel, or a better rail, by an increase in carbon and a reduction of phosphorus is theoretically ideal. To obtain steel rails with a guaranteed phosphorus-content lower than 0.10 per cent. is now impracticable from the majority of American rail-makers. The one Eastern rail-mill using pig-iron made entirely from Cuban ores can, without extra cost, make steel of a somewhat lower guaranteed phosphorus than the seven Western rail-mills using iron made from native ores. By a careful selection of ores, some of these latter mills could make a small tonnage of steel rails of a guaranteed phosphorus-content of 0.085 per cent.; but the extra cost and other trade conditions make this suggestion impracticable, and existing data as to wear does not warrant establishing a phosphorus guarantee below 0.10 per cent.

(*b*) *Foreign Specifications.*—Contrary to American specifications there is very seldom in foreign rail-specifications any change in the carbon and manganese with an increase in the weight of section. The maximum carbon is 0.50 per cent., usually with an allowable range of 15 points, except in the British standard specification for tramway rails of from 90 to 116 lb. per yd., where the carbon range is from 0.40 to 0.55 per cent.

Table II. also shows that the maximum manganese specified is 1.00 per cent., with allowable range of 30, but sometime 20 points.

There is considerable variation in the maximum silicon specified. The figures being 0.06, 0.07, 0.08, 0.10 and occasionally 0.15 and 0.20 per cent.

With sulphur, the maximum is either 0.080, 0.070 or 0.060 per cent.

The American mills have no objection to making the softer rails preferred by foreign engineers, and consequent upon maximum limits of 0.50 per cent. of carbon, 1.00 per cent of manganese and 0.080 per cent of silicon. They only need a range of 10 points in carbon, although often given, as above stated, a limit of 0.35 to 0.50 per cent. They want a range of 20 points in manganese, either from 0.80 to 1.00 per cent., or from 0.70 to 0.90 per cent., but they object to such low manganese as 0.40 per cent., which is occasionally specified. In reference to sulphur, a fair maximum would be 0.070 per cent.

As to phosphorus, the requirement in foreign specifications of older date, that every heat of rail-steel shall be analyzed for phosphorus and arsenic, and stipulating that together they must not exceed 0.60 per cent., has become obsolete. Arsenic should not be classed with phosphorus in its effect upon the physical qualities of steel, and furthermore, there is no rapid method by which phosphorus and all the arsenic can be determined in steel. Most of the current foreign rail-specifications limit the phosphorus to 0.080 or 0.075 per cent., although some published analyses of British rails show a higher phosphorus content than 0.080 per cent.

In discussing the American specifications, it was stated that all the American mills, except the one using foreign ores entirely, would not guarantee their output of steel rails under

TABLE II.—*Chemistry of Foreign Rail-Specifications, Arranged According to Weight of Section.*

50–59 Lb.			60–69 Lb.			70–79 Lb.			80–89 Lb.			90–100 Lb.			Silicon. Not Over.	Phosphorus. Not Over.	Sulphur Not Over.
Weight.	Carbon.	Manganese.	Weight.	Carbon.	Manganese.	Weight.	Carbon.	Manganese.	Weight.	Carbon.	Manganese.	Weight.	Carbon.	Manganese.			
	Per Cent.	Per Cent.		Per Cent.	Per Cent.		Per Cent.	Per Cent.		Per Cent.	Per Cent.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
...	....	....	60	0.35–0.42	0.75–1.00	75	0.35–0.42	0.75–1.00	80	0.35–0.42	0.75–1.00	100	0.35–0.42	0.75–1.00	0.10	0.080	0.060
...	....	....	65	0.35–0.42	0.75–1.00	...	....	....	85	0.35–0.42	0.75–1.00	...	....	....	0.10	0.080	0.060
50	0.30–0.45	....	...	....	....	75	0.30–0.45	....	85	0.35–0.50	Max. 0.80	...	....	....	0.06	0.080	0.060
...	....	....	...	....	....	75	0.30–0.50	Max. 0.80	82	0.35–0.50	Max. 0.80	...	....	....	0.06	0.080	0.060
30	0.30–0.45	0.80	...	....	....	...	....	....	...	....	....	...	....	....	0.06	0.080	0.060
50	0.30–0.45	0.80	...	....	....	...	....	....	...	....	....	...	....	....	0.06	0.080	0.060
...	....	....	...	....	....	...	....	....	...	....	....	95	0.40–0.50	0.85–0.95	0.10	0.080	0.080
...	....	....	...	....	....	...	....	....	85	0.35–0.45	0.70–0.95	...	....	....	0.10	0.080	0.070
...	....	....	...	....	....	72.8	0.40–0.50	Max. 1.00	85	0.40–0.50	Max. 1.00	...	....	....	0.08	0.075	0.070
...	....	....	60	0.30–0.45	Max. 1.00	...	....	....	...	....	....	...	....	....	0.10	0.075	0.070
...	....	....	...	....	....	...	....	....	...	....	....	100	0.40–0.50	0.80–1.00	0.08	0.075	0.070
...	....	....	...	....	....	...	....	....	83	0.40–0.50	0.70–1.10	...	....	....	0.15	0.080	0.080
...	....	....	60	0.38–0.48	0.70–1.00	...	....	....	...	....	....	...	....	....	0.20	0.100	....
...	....	....	...	....	....	...	....	....	80	0.42 Min.	Max. 1.10	100	0.45 Min.	Max. 1.10	0.20	0.100	0.080
...	....	....	...	....	....	...	....	....	80	0.40–0.50	0.80–1.00	...	....	....	0.15	0.080	0.080
...	....	....	...	....	....	...	....	....	...	....	....	90	0.40–0.55	0.70–1.00	0.10	0.080	0.080
...	....	....	...	....	....	...	....	....	...	....	....	116	0.40–0.55	0.70–1.00	0.10	0.080	0.080
...	....	....	60	0.35–0.50	0.70–1.00	70	0.35–0.50	0.70–1.00	80	0.35–0.50	0.70–1.00	90	0.35–0.50	0.70–1.00	0.10	0.075	0.080
...	....	....	65	0.35–0.50	0.70–1.00	75	0.35–0.50	0.70–1.00	85	0.35–0.50	0.70–1.00	95	0.35–0.50	0.70–1.00	0.10	0.075	0.080
...	....	....	...	....	....	...	....	....	...	....	....	100	0.35–0.50	0.70–1.00	0.10	0.075	0.080
20	0.35–0.50	0.70–1.00	...	....	....	...	....	....	...	....	....	...	....	....	0.10	0.070	0.070
40	0.35–0.50	0.70–1.00	60	0.35–0.50	0.70–1.00	70	0.35–50	0.70–1.00	80	0.35–0.50	0.70–1.10	90	0.35–0.50	0.70–1.00	0.10	0.070	0.070
50	0.35–0.50	0.70–1.00	65	0.35–0.50	0.70–1.00	75	0.35–50	0.70–1.00	85	0.35–0.50	0.70–1.10	95	0.35–0.50	0.70–1.00	0.10	0.070	0.070
55	0.35–0.50	0.70–1.00	...	....	....	...	....	....	...	....	....	100	0.35–0.50	0.70–1.00	0.10	0.070	0.070
...	....	....	60	0.30–0.45	Max. 1.00	...	....	....	...	....	....	...	....	....	0.07	0.075	0.070
...	....	....	...	....	....	...	....	....	80	0.30–0.45	Max. 1.00	...	....	....	0.07	0.075	0.070
...	....	....	...	....	....	...	....	....	...	....	....	98	0.40–0.50	0.50–0.80	0.12	0.060	0.060
...	....	....	60	0.30–0.45	Max. 1.00	...	....	....	...	....	....	...	....	....	0.07	0.075	0.070
...	....	....	...	....	....	...	....	....	...	....	....	92	0.35–0.50	0.75–1.00	0.10	0.080	0.080
...	....	....	...	....	....	...	....	....	87	0.40–0.50	0.70–1.10	...	....	....	0.15	0.080	0.080
...	....	....	60	0.38–0.48	0.70–1.00	...	....	....	...	....	....	...	....	....	0.20	0.100	....
...	....	....	...	....	....	70	0.40–0.50	0.75–1.05	...	....	....	...	....	....	0.20	0.100	0.070
...	....	....	...	....	....	75	0.40–0.50	0.75–1.05	...	....	....	...	....	....	0.20	0.100	0.070
...	....	....	60	0.35–0.50	0.75–1.00	...	....	....	...	....	....	...	....	....	0.10	0.080	0.100
...	....	....	60	0.38–0.48	0.70–1.00	...	....	....	...	....	....	...	....	....	0.20	0.100	....
...	....	....	60	0.35–0.45	Max. 0.90	...	....	....	...	....	....	...	....	....	....	0.100	....
...	....	....	...	....	....	...	....	....	80	0.45–0.50	0.85–0.95	90	0.45–0.50	0.85–0.95	0.06	0.080	0.080
50	0.30–0.45	Max. 0.80	60	0.35–0.50	Max, 0.80	...	....	....	...	....	....	...	....	....	0.06	0.080	0.060
...	....	....	...	....	....	...	....	....	86	0.35–0.50	0.75–1.00	...	....	....	0.10	0.075	0.080
...	....	....	...	....	....	...	....	....	85	0.35–0.45	0.85–0.95	...	....	....	0.10	0.080	0.080
...	....	....	...	....	....	...	....	....	80	0.42 Min.	Max. 1.10	100	0.45 Min.	Max. 1.10	0.20	0.100	0.080

0.10 per cent. of phosphorus. It is, therefore, evident that to obtain tenders from several American mills, the foreign engineer should modify his specified phosphorus to 0.10 per cent. from the present limits of 0.075 or 0.080 per cent., which English makers of acid Bessemer steel rails can meet, without extra cost, having the Cumberland and Spanish hematites, of lower phosphorus than the American ores, as a basis of their ore-mixtures. With the low carbon specified, this change, resulting in free competition, is not as serious as might at first appear.

The engineer knows that even the steel-maker grants that phosphorus is the most undesirable constituent of steel. He knows that, in general, when a steel is liable to sudden and frequent shock, it should be "low in phosphorus." He must bear in mind, however, that careful heating and lower finishing-temperatures easily overcome a difference of 0.020 per cent. in phosphorus; moreover, that it is universally conceded that the evil effects of phosphorus increase with the carbon; that the foreign engineer's rail-specifications call for a lower range of carbon than is usually specified in America; that the higher carbon American rails with their 0.10 per cent. of phosphorus withstand the shock of the drop-test, and that it has not been proven that any difficulties with breakage on American roads or on foreign roads laid with American rails have been attributed to the presence of 0.10 per cent. instead 0.08 per cent. of phosphorus in the rails. Nor in foreign service have American rails been proven more brittle than those of British make.

Finally, he should bear in mind that this modification in phosphorus is by no means a new suggestion, as it has often been allowed; a fact emphasized by the official statistics, which show that in the last ten years 2,262,451 gross tons of rails have been exported from the United States, and that therefore, abroad as well as in America, there is a considerable tonnage of rails containing a little less than 0.10 per cent. of phosphorus, now in track, and meeting the service demanded.

Basic open-hearth, or even basic Bessemer rails with their very much lower phosphorus-content, if other hardening-constituents were present in the right proportion and other even more important details of manufacture were properly carried out, would perhaps give better and longer service; but under

present conditions, the vast majority of rails rolled in England and America for some time to come will be made of acid Bessemer steel.

Under these commercial conditions, and in view of the facts presented, and the other requirements of his specification, which in themselves amply protect his client, is the engineer warranted in restricting competition by refusing to change his phosphorus limit to 0.10 per cent so as to include current American practice?

2. *Chemical Analysis.*

(*a*) *American Specifications.*—In American specifications, the manufacturer is required to furnish the inspector daily with carbon determinations from each blow, and a complete chemical analysis every 12 or 24 hr., representing the average percentage of manganese, phosphorus, sulphur and silicon present.

All these analyses are made on drillings taken from the test ingot, cast when pouring the heat, and check-analyses on rails are not required.

(*b*) *Foreign Specifications.*—The demands on the steel-works laboratory and the possible delays resulting from independent check-analyses are of such importance to the American rail-mill, when the foreign requirements are applied to American output, that the necessity for such frequent analyses and the emphasis given to checking results will be discussed somewhat in detail.

(*c*) *Number of Analyses Required.*—In some foreign rail-specifications, the maker is asked to furnish complete chemical analyses more frequently that can possibly be complied with, when the requirements are applied to American practice; even with the facilities of the modern rapid analytical methods, the result of the conscientious efforts of steel-works' chemists, fail to meet the demands made on them.

It is unnecessary in American practice to obtain such frequent checks, for in the present state of the art, the "direct metal," as delivered to the Bessemer vessel, is smelted from a uniform mixture of ores, so that the variation in phosphorus is small, and the "blowing" is so constant and regular that temperatures vary within narrow limits, and hence the silicon in the steel is practically constant. As to reports on carbon and manganese, the maker is willing to furnish them with every

blow of steel; also phosphorus determinations on six blows of steel every 12 hr., and sulphur and silicon on an average sample of each 12 hours' rolling.

(*d*) *Sample for Analysis.*—Drillings from a test ingot, cast during pouring, is the only practicable method by which an identified average sample of a heat of steel rolled into rails can be obtained, and American mills refuse to allow analyses of drillings from rails or tensile tests to govern the decision of the inspector as to the chemical composition of a heat of rails, because such samples are not representative.

It is well known to the consulting engineer and his representatives at the mill, as well as to the manufacturer, that there is an unavoidable variation in the composition of the different rails from each blow, as well as those from each ingot, a difference between the two ends of a rail, and, in point of fact, unavoidable variations even in the different portions of the cross-section. It is, therefore, unreasonable to specify that check-analyses shall be made on rails, and that the finished rails shall be piled into 500-ton lots and not shipped until an analysis on one piece of rail is reported by some independent and probably far-distant chemist, who has been selected by the engineer.

If the average chemical composition of a piece of rail is to be determined, there is only one correct way of obtaining an average sample; namely, to machine dry clean chips from the entire cross-section of the rail for a uniform depth, weigh the entire sample, dissolve it all in acid, dilute the solution to a known volume and measure off aliquot portions for the determination of manganese, silicon and phosphorus; again machine the entire cross-section for a smaller depth, and use all the chips for a gravimetric determination of carbon, preferably by combustion in oxygen; again machine the cross-section and use all of the sample for the determination of sulphur.

No chemist can dispute the above statement, and yet many steel chemists will admit that they have been requested to analyze drillings from rails which they knew did not truly represent the piece of rail selected as a sample, much less the 500 tons which the inspector was privileged to accept or reject on the basis of the reported analysis.

(*e*) *Check Analysis Impracticable.*—The laboratories of the large American steel-works are in charge of competent chem-

ists using modern methods. Their work is regularly checked by American customers buying merchant steels on guaranteed analyses. Standard samples of pig-iron and steel, which have been carefully analyzed, are now furnished at low cost by the Bureau of Standards at Washington, for the purpose of checking chemists' results. A steel-works chemist, by virtue of the many similar determinations he is daily required to make, becomes a specialist in his line, and it is no injustice to claim that his results are at least as accurate as those of independent chemists, whose analytical work usually covers a much wider field.

For these reasons, the American rail-maker, who willingly furnishes a sufficient number of analyses daily to form a correct guide of the chemical composition of his product is justified in declining to comply with the many forms of check-analyses found in foreign rail-specifications, if his product may be thus rejected without appeal, and when it is specified and these independent analyses may be made "as often as desired" and "at the expense of the contractor."

It is impracticable in American practice to re-handle the finished rails, sorting them out in piles of 200 or 500 tons, and it is entirely unjust, as will be shown in the discussion immediately following, for such lots to be rejected solely on the analysis of a single rail.

(*f*) *Rejection Solely on Variation in Composition.*—The provisions of foreign rail-specifications for the rejection of rails solely on the basis of a variation from the prescribed chemistry are too strictly drawn, and the suggestion as to check-analyses is impracticable.

In studying the prompt and frequent analyses furnished by the manufacturer, of the rail steel made on each turn, it is but reasonable that the inspector should be given the authority to exercise some judgment, when the analyses show only a slight and immaterial variation from the specified limits. By so doing, he is not jeopardizing the interests of the purchaser, but simply acknowledging that accuracy within 0.005 per cent. in phosphorus, sulphur and silicon, and 0.01 per cent. in carbon and manganese, in not uniformly attainable with the rapid methods of analysis necessarily employed, and he is further supported in a sensible tolerance in this regard by the knowl-

edge that no such small variations from the prescribed limits in chemistry can possibly effect the life, the safety or the wear of the rails when put in service.

Furthermore, no prescribed methods for chemical analyses should form a part of a specification. Entire uniformity in the details of the various analytical methods used in steel-works laboratories will probably never be realized, nor is it a necessity in obtaining accurate chemical analyses.

IV. Physical Properties.

1. *Drop-Test and Drop-Testing Machine.*

(*a*) *American Specifications.*—As one of the results of the standardization of rail specifications in America, the American rail-mills are equipped with a drop-testing machine uniform in its essential features.

The tup weighs 2,000 lb.; the radius of its striking-face is 5 in. The weight of the anvil block is amply sufficient to secure rigidity; and it furthermare rèsts on a solid masonry foundation. The supports for the rails have a 5-in. radius, are set 3 ft. apart and are firmly secured to the anvil block. The height to which the tup is raised is measured in even feet, by a fixed vertical gauge.

The drop-test is made on a piece of rail, from 4 to 6 ft. long, cut at the hot saws, from the end of one rail from every fifth heat. The piece is stamped with the blow number and placed on skids to cool. When cool and ready for test, it is placed head upwards on the supports, and the various sections must withstand, without fracture, one blow of the 2,000-lb tup, from the heights specified. The report of this drop-test includes a record of the atmospheric temperature at the time the tests were made.

None of the American specifications require a second blow from the tup, and, with but one or two exceptions, no deflection-limits are specified.

In case the rail-butt, selected to represent the heat, as above described, should break when subjected to the drop-test, two additional drop-tests are made on pieces of rail or on rail-butts cut from two other rails from the same blow of steel; if either of these latter tests fail, all the rails of the blow which they

represent are rejected, but if both of these additional test-pieces meet the requirements, all the rails of the blow which they represent will be accepted. If a heat of rails is thus rejected, the blow next preceeding and succeeding the rejected blow is similarly tested, and if the rails of either of these blows are rejected, provision is made for similarly testing adjacent blows until the entire group of five blows is tested, if necessary. Each blow is accepted or rejected, according to the result of the drop-test on the test-rails representing the blow.

Table III. gives the heights of drop required in the specifications governing the vast majority of the tonnage of domestic rails delivered to American railroads. The chemical requirements are included for comparison; the "foot pounds" noted are simply the product of the weight into the height, without regarding the energy of the tup just before striking. The comparative resistance to impact of rails, of a certain weight per yard, is influenced by the section. As more than 80 per cent. of the rails now rolled for American railroads are the standard "T" sections recommended in 1893 by the American Society of Civil Engineers, the weight and the chief measurements of these standard sections are also included in Table III. so as to aid in comparing the American drop-test on "T" rails of certain weights and dimensions, with that required for the wide variety of sections included in foreign specifications.

(*b*) *Foreign Specifications.*—A tabular comparison of the drop-test, as is found in foreign rail-specifications, would only emphasize the diversity of the requirements specified. Since the specifications are based on British practice, the number of tests usually required should be reduced when applied to American practice, so as not to retard the output; this concession is reasonable because the inspector is given the carbon- and manganese-content of each heat before the rails are rolled, and the continuous methods characteristic of American rail-mills makes but slight differences in the finishing-operations. With the chemical composition already known, a drop-test on each heat is therefore not necessary, and with the production of more than 125 heats per 24 hr., this requirement operates as a hardship on the manufacturer as well as on the inspector.

A few specifications make no allowance for re-test, in case the piece cut from the end of one rail of the heat fails under the

TABLE III.—*Drop-Tests of American Rail-Specifications.*

Weights per Yard for Chemical Requirements	50-59 Lb. per Yd.				60-69 Lb. per Yd.		70-79 Lb. per Yd.		80-89 Lb. per Yd.		90-100 Lb. per Yd.	
Carbon	0.35-0.45 per cent.				0.38-0.48 per cent.		0.45-0.55 per cent.		0.48-0.58 per cent.		0.50-0.60 per cent.	
Manganese	0.70-1.00 per cent.				0.70-1.00 per cent.		0.75-1.05 per cent.		0.80-1.10 per cent.		0.80-1.10 per cent.	
Silicon	Not over 0.20 per cent.				Not over 0.20 per cent.		Not over 0.20 per cent.		Not over 0.20 per cent.		Not over 0.20 per cent.	
Phosphorus	Not over 0.10 per cent.				Not over 0.10 per cent.		Not over 0.10 per cent.		Not over 0.10 per cent.		Not over 0.10 per cent.	
Weights per Yard for Drop-Tests	45-55 Lb. per Yd.				55-65 Lb. per Yd.		65-75 Lb. per Yd.		75-85 Lb. per Yd.		85-100 Lb. per Yd.	
A. S. C. E. Standard "T" Sections.												
Weight per Yard	40	45	50	55	60	65	70	75	80	85	90	100
Height	$3\frac{1}{2}$ In.	$3\frac{11}{16}$ In.	$3\frac{7}{8}$ In.	$4\frac{1}{16}$ In.	$4\frac{1}{4}$ In.	$4\frac{7}{16}$ In.	$4\frac{5}{8}$ In.	$4\frac{13}{16}$ In.	5 In.	$5\frac{3}{16}$ In.	$5\frac{3}{8}$ In.	$5\frac{3}{4}$ In.
Width of Base	$3\frac{1}{2}$ In.	$3\frac{11}{16}$ In.	$3\frac{7}{8}$ In.	$4\frac{1}{16}$ In.	$4\frac{1}{4}$ In.	$4\frac{7}{16}$ In.	$4\frac{5}{8}$ In.	$4\frac{13}{16}$ In.	5 In.	$5\frac{3}{16}$ In.	$5\frac{3}{8}$ In.	$5\frac{3}{4}$ In.
Width of Head	$1\frac{7}{8}$ In.	$2\frac{1}{16}$ In.	$2\frac{1}{8}$ In.	$2\frac{1}{4}$ In.	$2\frac{3}{8}$ In.	$2\frac{15}{32}$ In.	$2\frac{7}{16}$ In.	$2\frac{15}{32}$ In.	$2\frac{1}{2}$ In.	$2\frac{9}{16}$ In.	$2\frac{5}{8}$ In.	$2\frac{3}{4}$ In.
Thickness of Webb	$\frac{25}{64}$ In.	$\frac{27}{64}$ In.	$\frac{7}{16}$ In.	$\frac{15}{32}$ In.	$\frac{31}{64}$ In.	$\frac{1}{2}$ In.	$\frac{33}{64}$ In.	$\frac{17}{32}$ In.	$\frac{9}{16}$ In.	$\frac{9}{16}$ In.	$\frac{9}{16}$ In.	$\frac{9}{16}$ In.
Height of Drop	14 Ft.				15 Ft.		16 Ft.		17 Ft.		18 Ft.	
Equivalent to Foot Pounds	28,000				30,000		32,000		34,000		36,000	

impact test. Usually, however, privilege is given to submit tests cut from two other rails from the heat, and the heat is rejected if two out of three tests fail.

As the specified distance between supports is never over 4 ft., and usually not over 3.5 ft., it simply makes the manufacturer unnecessarily consign good metal to scrap, for the engineer, as is sometimes done, to specify the test of pieces over 5 ft. long or of a full-length rail.

When the drop-test accepts or rejects the product by heats, the further check of one test cut from every 100 or 200 rails, as is sometimes specified, seems unnecessary.

There is one form of foreign drop-test which acts as a hardship on the American mills if made as specified on "one rail-butt from each heat." The test requires that a piece of rail, with 4 ft. between supports, shall be given two blows with a 1-ton tup from sufficient heights to bend the rail to an angle of 110° (that is, through an angle of 70°); the specified carbon is from 0.35 to 0.42 per cent. It seems illogical to specify this fixed angular deflection for all sections and weights of rails, and it is questionable whether this requirement can be obtained from the heavier sections under the conditions specified.

Specified drop-tests, such as the following, are entirely impracticable when applied to American output: after the regular drop-test, it is specified that "the rails are also to be tested until broken, the heights of fall and number of blows being recorded;" also, "butts of rails will be subjected to drop-tests until broken, and if the metal fails to show 4 per cent. of elongation before breaking, the whole lot of rails made from the heat will be rejected."

(c) *Limits in Deflection.*—As a general rule, an American rail will not show quite as much deflection under impact as a similar section of British make. One reason is that the carbon specified by foreign engineers is so much lower than American practice that the natural tendency of the manufacturer is to approach the upper limit of the permissible range, as they are not accustomed to make rail-steel below 0.40 per cent. of carbon; another, that the finishing temperature also differs somewhat from that of British mills.

American mills do not hesitate to guarantee that their rails, rolled to the required foreign section and to the chemistry speci-

fied, will show entire freedom of brittleness under an impact test made by their drop-test machine, if measured by the ability of the rails of various weights to withstand one blow, equivalent to the foot-pounds contained in Table III. Since a rail, if brittle, will fail on the first blow, a continuance of the testing, as well as a specified range of deflection between narrow limits, seems unnecessary.

The drop-test is a check on brittleness; the fact that a rail of a certain section as delivered from an American mill will not show as much deflection as a similar rail of British make, is not proof that the American rail will prove less safe, and as far as resistance to wear is concerned, there is no evidence that, under like conditions, the American rail is giving an inferior service; in fact, there are indications that the stiffer rail is not unsafe and gives better wear than the softer rail which showed, when inspected at the mill, a greater deflection under impact. Furthermore, the stiffer rail insures a longer life to the rolling-stock.

Deflections are therefore omitted in the proposed standard specifications appended to this paper.

2. *Tensile Test.*

This requirement is so frequently found in foreign rail-specifications, that its actual value, as well as the difficulties encountered in applying it to American practice, to the extent that it is usually specified, will be discussed somewhat in detail.

(*a*) *American Specifications.*—None of the American rail-specifications include a specified tensile strength, elongation or contraction of area, because the data thus accumulated are not considered of any practical value to the purchaser.

(*b*) *Foreign Specifications.*—As a result, the American rail-mills are not especially equipped to machine rapidly tensile specimens from the rails and determine promptly the tensile strength and elongation. They therefore object, in general, to any tensile requirements, and especially to specifications in which a tensile test is required so frequently as to render it impossible to keep the testing up to their tonnage output, no matter how well they might equip themselves to meet this requirement, found only in foreign rail-specifications.

It is not just to the manufacturer to require him to furnish

rails within certain limits in tensile strength, elongation and sometimes reduction of area, when the specification also requires the steel to be within a certain range in carbon and manganese, and of a certain limit in silicon, and when the maker willingly furnishes prompt determinations of carbon and manganese in every heat of steel rolled into rails, and also meets a specified drop-test.

(c) *Test Pieces are not Representative.*—The actual value of this requirement is doubtful, because the tensile specimen, at the best, but imperfectly represents the strength of the steel in the rail selected for test; furthermore, no data have been presented proving that the results obtained on tensile specimens, as cut from rails, bear any relation to the wear of the rails in service.

(d) *Specified Tensile Strength is Affected by the Section.*—With the same specified range in chemical composition for rails weighing 20 lb. to the yd., and those 100 lb. to the yd., it is manifestly inconsistent to require the steel to come within the same limits in tensile strength and meet the same minimum elongation, and thus take no cognizance of the more rapid cooling of the lighter sections.

Table IV. gives examples of foreign rail-specifications where the same tensile strength and elongation is required for a wide range of sections. The injustice of this disregard of the effect of the section is emphasized when, as noted, these same specifications permit the rejection of all the rails of a blow, if the tensile tests from one to three rails fail to meet the requirements.

(e) *Specified Tensile Strength is Often Inconsistent with the Specified Chemistry.*—It has been stated above, that it is not just to hold the manufacturer to a specified chemistry, and in addition require him to meet definite limits in tensile strength, elongation and contraction of area. In some foreign rail-specifications this injustice is, if possible, emphasized by the engineer requiring physical properties which cannot be met at all, if the manufacturer adheres to the specified chemistry. The required elongation is often too high for even the minimum tensile strength specified, to say nothing of the maximum tensile strength which should, in no event, be included in rail-specifications.

TABLE IV.—*Quotations from Foreign Rail-Specifications in which the Same Tensile Strength and Elongation is Specified Independent of the Weight of the Rail Section.*

Weight of Rail.	Tensile Strength, Per Sq. In.		Elongation.	Failure of these Tensile Requirements Cause Rejection.
Pounds Per Yard.	Tons.	Pounds.	Per Cent.	
90 to 116	Not less than 40	Not less than 89,600	12 per cent. in 2 in.	One rail tested from each 100 tons. On failure of first test, a test from another rail from same blow is allowed; if this latter test fails, all the rails of the blow are rejected
60 to 100	38 to 45	85,120–100,800	15 per cent. in 3 in. or 2 in.	Same as above.
20 to 100	40 to 48	89,600–107,520	15 per cent. in 3 in. or 2 in.	One rail tested from each 100 tons. On failure of first test, a test from two other rails from same blow is allowed; if two of the three tests fail, all the rails of the blow are rejected.
65 to 100	38 to 42	85,120–94,080	12 per cent. in 2 in.	Tests made on one or more rails from each 100 tons.
55 to 88	35.3 to 41.3	78,227–92,450	14 per cent. in 7.87 in.	One half of 1 per cent. of rails are tested. If the tested rail fails, all rails of the blow are rejected

In compiling Table V., which shows at a glance the various inconsistencies above referred to, only the range in carbon was included, since in the specifications quoted, the manganese limits were all between 0.70 to 1.00 per cent., and the required silicon 0.10 per cent., or under.

Tensile tests should be eliminated entirely for the reasons already given; but if the engineer will not waive them, they should at least be consistent with the chemistry required, and which is furnished with every heat,—especially when the failure to meet the specified tensile strength and elongation is in itself a cause for the rejection of all the rails of the blow thus tested.

(*f*) *Specified Tensile Strength is Often Inconsistent with Specified Elongation.*—A study of Table V. shows, in one case, that for rail-steel of 47.6 tons (106,673 lb.) minimum tensile strength, the required elongation is 11 per cent. in 7.87 in.; in two cases

TABLE V.—*Comparison of the Chemical and Tensile Requirements of Some Foreign Rail-Specifications.*

Carbon Specified.	Minimum Requirements.			
	Tensile Strength per Sq. In.		Elongation.	Reduction of Area.
Per Cent.	Tons.	Pounds.	Per Cent.	Per Cent.
0.30–0.35	35	78,400	20 per cent. in 2 in.	....
0.35–0.42	38	85,120	12 per cent. in 2 in.	....
0.35–0.45	38	85,120	20 per cent. in 2 in.	....
0.35–0.45	40	89,600	20 per cent.	....
0.35–0.50	37	82,880	20 per cent. in 2 in.	25
0.35–0.50	38	85,120	15 per cent. in 3 in. or 2 in.	....
0.35–0.50	38	85,120	15 per cent.	....
0.35–0.50	40	89,600	15 per cent. in 3 in. or 2 in.	....
0.35 Min.	41.3	92,450	18 per cent.	....
0.40–0.50	37	82,880	15 per cent. in 3 in.	....
0.40–0.50	40	89,600	20 per cent. in 2 in.	....
0.40–0.50	40	89,600	20 per cent. in 2 in.	....
0.40–0.50	40	89,600	20 per cent.	....
0.40–0.50	43	96,320	12 per cent. in 10 in.	20
0.40–0.50	43	96,320	12 per cent. in 10 in.	35
0.40–0.50	47.6	106,673	11 per cent. in 7.87 in.	20 to 30
0.40–0.50	47.6	106,673	8 per cent. in 7.87 in.	15 to 20
0.40–0.55	40	89,600	12 per cent. in 2 in.	....
0.40 Min.	35.3	78,227	14 per cent. in 7.87 in.	....
0.45–0.50	30	67,200	20 per cent. in 8 in.	....

where the minimum tensile is 43 tons (96,320 lb.) the steel must show 12 per cent. stretch in 10 in. With the shorter gauged length of 2 in., a number of specifications require 20 per cent. elongation with a minimum tensile of from 28 to 40 tons (85,120 to 89,600 lb.). All these percentages of elongation are too high, especially as in one case the allowable range in carbon is from 0.40 to 0.50 per cent.

(*g*) *Amount of Tensile Testing Required is Excessive.*—In some foreign rail-specifications, the important matter of the number of tensile tests required, is left in doubt by such expressions as "the inspector will occasionally test the rails for tensile strength," or "will test the rails for tensile strength from time to time." Usually, however, the number of tensile tests are definitely specified, and as they are based on English practice, they form a great hardship when applied to American mills, and if literally carried out would hold back the output by causing a serious congestion in loading.

The American mills most frequently rolling rails for export produce from 1,800 to 2,200 tons of finished rails every 24 hr. Assuming 2,000 tons, and that an 80-lb. 33-ft. rail is being

rolled, this tonnage is equivalent to 5,100 rails per 24 hr. On this basis, the number of tensile tests required from American mills per day, by various foreign rail-specifications, would be as follows:

TABLE VI.—*Number of Tensile Tests in Foreign Rail-Specifications.*

Requirements of Foreign Rail-Specifications.	American Output Equivalent.
"One from each 100 tons."	20 tensile tests per day.
"One from every 250 rails."	20 tensile tests per day.
"Three every 250 rails."	60 tensile tests per day.
"One per cent. of number of rails rolled."	51 tensile tests per day.
"Not over half per cent. of number of rails rolled."	Not over 26 tensile tests per day.
"Not over 2 per cent. of day's rolling."	Not over 102 tensile tests per day.
"One from every fifth cast."	20 to 40 tensile tests per day.

But even Table VI. does not represent the amount of tensile testing required by foreign rail-specifications.

Specifications calling for a test from "one rail in every 100 tons," also stipulates that the engineer can require the manufacturer to prepare extra test-specimens, for independent test, to the extent of "two every 200 tons of product," equivalent to 20 additional test specimens per day.

Another specification requiring that "one or more rails from each 100 tons" be regularly tested for tensile strength, also demands that tensile specimens must be prepared and tested "from every rail which in the drop-test fails under two blows to bend through an angle of 70 degrees."

Another specification requiring that a tensile test to be cut "from one finished rail, to the extent of one per cent. of each days' rolling" (namely, 51 tests per day), also states "in addition to the tests made on one per cent. of the rails, a tensile test is to be made from crop-ends representing each of the remaining charges."

(*h*) *Conclusions.*—It has been said that, with specified carbon, manganese, silicon and phosphorus, and also a drop-test, it is unreasonable to demand tensile tests also; that the tensile strength, as determined in rails, has not been proved to bear any relation to the wear of the rails in service; that it is effected by the section; that, as specified, it is often inconsistent

with the required chemistry and elongation; and that the number of tests demanded is very excessive. It is worthy of note that the three British standard rail-specifications, while specifying tensile tests, leave the enforcement of this requirement optional with the engineer.

For the reasons above given, and also because this test is often not actually required to the extent specified, it has been entirely omitted in the proposed standard rail-specification appended to this paper.

3. *Dead-Weight Test.*

(*a*) *American Specifications.*—None of the American rail-specifications include a static test. This test, like the tensile test just discussed, is, in American practice, also considered as an unnecessary check on the product, when chemical composition and a drop-test are specified.

(*b*) *Foreign Specifications.*—This transverse test under static load is still found in many foreign rail-specifications. It has been omitted in the three recent British standard rail-specifications, and is also not now included in the rail-specifications of a number of noted British engineers.

The test may be divided into two classes:—

1. The test confined to subjecting the rail, laid on roller-supports a specified distance apart, to a specified load for a stated time, said load (from 12 to 28 gross tons) being within the elastic limit of the steel. After this load has been applied for a stated length of time (5, 15 or 30 min.), the deflection is measured, and it is specified that this deflection shall not exceed a certain amount (usually between the limits of from $\frac{3}{16}$ to $\frac{1}{2}$ in.), and that, after the removal of the load, no permanent set shall have taken place.

2. A continuance of the above test, consisting, after the deflection due to the first application of the load has been measured, in an increase of the load, by regular increments, up to usually twice the original load; the rail must have then deflected between 1 and 2 in., and, on removal of the load, the permanent set must be not over $1\frac{3}{8}$ in.

Studying foreign rail-specifications with reference to the first method, where the specified load is below the elastic limit, the fact that the deflection is largely a factor of the section seems,

in some cases, not to have been given due consideration; for example:—while a load of 12 tons with 3 ft. between supports is specified for "T" rails weighing 43, 45, 46 and 50 lb. per yd., yet this same load is specified for 73- and 85-pound "T" rails, the only difference being 5 ft. between supports. In three specifications the specified loads for 60-lb. "T" rails are 15, 16 and 21 tons, with 3 ft. 6 in. between supports in each case. With 3 ft. between supports in both cases, the load for a 70-lb. "T" rail is in one case 22 tons, whereas in the other only a 23-ton load is required for a 90-lb. bull-head rail. In one case, with an 80-lb. "T" rail the required load is 24 tons with 4 ft. between supports, whereas with 3 ft. between supports, a 90-lb. bull-head rail is tested with a 23-ton load.

In two specifications, with the same chemistry, the same distance between supports and the same maximum deflection of $\frac{3}{8}$ in., the specified load for a 60-lb. "T" rail 4 in. in height is 16 tons, as compared with a 28-ton load for a 75-lb. bull-head rail 5 in. in height. There is another criticism that is pertinent; namely, that after requiring the manufacturer to put a piece of rail under a load below its elastic limit, there is often no mention as to the amount of deflection required; the length of time under which the rail shall remain under test is also sometimes omitted.

The chief objection to the second class of dead-weight tests, where the loading is gradually brought up to double the initial load, is the length of time occupied in properly making the test.

(c) *Number of Tests Specified.*—The inconsistencies above noted in the dead-weight test, and the doubt, owing to the frequent omission of important details as to exactly how the inspector will require the test to be made, make this requirement an uncertain factor in the cost of manufacture, and an important item in the cost, should the inspector carry out the number of tests actually specified, particularly since, in the majority of cases, it is specified that a failure to meet the requirements of the dead-weight test results, in itself, in the rejection of the blow represented by the rail tested. It is often specified that the test shall be made on a full-length rail, or a piece from 10 to 12 ft. long; in this case, the test cannot be obtained until after straightening, which leaves but little time for the actual

test, before the rails of the cast are drilled and ready to load. As to the number of dead-weight tests specified, as an actual check on the output, the same remarks as made on p. 650 apply to the impracticability of such clauses as "one rail from every blow;" "one rail out of every 100;" "one rail out of every 500;" "one per cent. of the number of rails rolled per day;" "at least three rails out of every 250."

It can be positively affirmed that it is utterly impossible, with the output of American mills, to have a dead-weight test applied as a regular check on the stiffness or hardness of a percentage proportion of the output. If it is not so applied, it should not be included in the tests which, on failure, cause rejection. If it is not classed with tests causing rejection, it seems useless to make it at all, although, of course, the manufacturer should have no objection to making a few tests on each day's output to show that the rails will stand a certain specified weight without permanent set, but continued tests to be within certain deflection-limits should be waived.

In the specifications proposed as a standard and appended to this paper the dead-weight test has been omitted.

4. *Bending-Test.*

(*a*) *American Specifications.*—One or two American rail-specifications include a bending-test on bars rolled or forged from small test-ingots cast while teeming the heat. In practice, this test is not required.

(*b*) *Foreign Specifications.*—In some foreign rail-specifications certain bending-tests are given sufficient prominence to be a ground for rejection of the blow of steel if failure occurs, and they must, therefore, be duly considered in a critical review of foreign requirements, made with reference to establishing a standard rail-specification, including all necessary checks on the product, and under which satisfactory rails for export can be furnished from American mills.

In some cases, it is suggested that a small ingot be cast from metal taken by a hand-ladle from the stream during the operation of filling the first ingot-mold and similarly from the last mold when tapping the ladle into some 6 or 8 ingots, which entire operation occupies in all only from 7 to 12 min. It is required that these small ingots, 2.5 by 2.5 in., or 3 by 3 in. by 4

or 6 in. long, be rolled or forged into 0.5-in sq. bars. A piece of this bar about 12 in. long is required to bend cold 90° without fracture. The practical value of such a test is not worth the trouble taken in making it. It originated before the present rapid and accurate method for the determinations of the carbon and manganese were perfected, and these more accurate checks which are now willingly reported on each heat as blown, should now be substituted.

In some foreign rail-specifications bending-tests are required on pieces cut from rails. In one case "one rail in every 100 tons must be bent sideways, by pressure, to a curvature of 10 ft. radius without any sign of fracture"; in another, "a short piece shall be bent by hammering cold to an angle of 95° with an internal radius of curvature of not more than 3 in. without showing fracture"; in another, the "piece of rail being placed flat must bend cold on a radius of 75 meters (246 ft.) without showing any crack"; in another, "one rail from each 100 tons must bend sideways, by pressure, to a curve of 30 ft. radius without cracking."

The British Standard's Committee includes a full size bending-test for heavy tramway rails, but then leaves it optional with the engineer, and they omit the test altogether from the standard specifications for bull-head and flat-bottomed rails.

To make these full-sized bending-tests requires heavy hydraulic presses; to make them a frequent check, which, on failure, rejects a proportion of the product, is impracticable in American practice. The specified drop-test and chemistry is a sufficient check on toughness.

For the above reasons, bending-tests on small pieces and on rails are omitted in the proposed standard specifications added to this paper.

V. SECTION.

1. *American Specifications.*

In 1881, A. L. Holley reported that American rail-mills had 188 different sections that were considered as standards, and that of these 119 patterns of 27 different weights per. yd. were regularly manufactured. In 1893, a special committee of the American Society of Civil Engineers recommended for adoption standard "T" sections for 12 different weights of rail, varying

by 5 lb., from 40 to 100 lb. per yd. In February, 1906, their Rail Committee reported on statistics received from eight of the nine rail-mills in the United States, showing that, on an average, for the year ending June 30, 1905, more than 80 per cent. of their total output were rolled to what has now become popularly known as the "A. S. C. E. rail-sections."

These conditions have naturally simplified the clauses in American specifications covering the actual approval of templets, and none of the American specifications require the engineer's approval of a sample-piece of rail before rolling. It is the uniform practice in America to allow a variation of $\frac{1}{64}$ in. less and $\frac{1}{32}$ greater than the specified height, and almost all specifications contain a clause reading that "unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with the paragraph relative to specified weight." This latter provides that the weight of the rails shall be maintained as nearly as possible after complying with the paragraph relative to allowable variation from templet; a tolerance of 0.5 per cent. in weight being allowed on an entire order.

In actual practice, these requirements have been found a sufficient check to prevent any complaint from the purchaser. Usually not more than 6,000 tons of rails are rolled without dressing-rolls, and one rail every hour is weighed to maintain uniformity in the product.

2. *Foreign Specifications.*

(*a*) *Templets.*—It is specified that the manufacturer shall prepare and submit for approval, templets of both rail and fish-plates, and in some cases stud- and plug-gauges to check accuracy in drilling; later he must supply one or two full sets of templets, engraved as specified.

On export orders, American mills should comply with all reasonable requests in this regard. The duplicate templets for record are made of German silver or brass, and engraved as specified.

(*b*) *Sample Piece of Rail.*—The British standard specifications omit the requirement contained in some foreign specifications that even after the approval of templets the manufacturer must

submit short lengths of rail, prepared under ordinary conditions, with bolt-holes in position for a complete fish-joint; the rolling not to proceed until the engineer has given written notification of his approval of the sample section of rail. It is unnecessary, after approval of templets, to require the mill to put in the rolls to furnish short sample-pieces before proceeding to fill the order, but after the rolling is regularly under way, these sample-pieces, fitted with splice-bars and bolts complete, should be willingly furnished if desired.

(*c*) *Allowable Variation From Templet.*—While properly insisting that the section shall be accurate to the approved templet throughout the rolling, some foreign specifications do not make provision for the unavoidable wear of the rolls. American mills agree to maintain a perfect fit of the splice-bars at all times, but require the variations in height above mentioned, which is now the standard American practice.

VI. Weight.

1. *American Specifications.*

The uniform practice as to tolerance in section is naturally followed up in American specifications by a uniform tolerance in weight, the allowable variation in all specifications being ½ per cent. on the entire order. Some variation from theoretical weight is unavoidable, and after limiting this variation in section and in weight to what is considered good standard practice, all American specifications then allow the rails to be accepted and paid for according to actual weights.

In practice there is no complaint from this logical method of billing rails. The mill weighs one rail every hr., which is the best and quickest method of keeping the product uniform.

2. *Foreign Specifications.*

The tolerances in weight specified by different foreign engineers are far from uniform; in some cases less and in some more leeway is given than necessary in good standard practice. Some sections are more difficult to roll than others. It is certainly unfair to bill rails on theoretical weights, or on the basis of the average of actual weights of a small percentage of each day's rolling; this necessitates considerable re-handling of finished rails to no practical advantage.

VII. Length.

1. *American Specifications.*

Requirements and practice are uniform in recognizing as a standard either a 30- or 33-ft. rail. All specifications permit the maker to deliver shorter rails to an amount equal, if necessary, to 10 per cent. of the entire order, but these rails must be cut, in even feet, down to either 24 or 27 ft.

A variation of 0.25 in. longer or shorter than standard length is uniformly allowed.

2. *Foreign Specifications.*

There are a number of lengths defined as standard in different foreign specifications. Some specifications recognize the justice of allowing the maker to furnish some rails shorter than standard, but leave in doubt the percentage allowance and the variations of length. Rails ordered cut to special lengths, for curves, should not be classed as short rails. If a large number of special lengths are specified, an extra charge for cold sawing and excess of scrap should be expected. Matters such as these, having a direct bearing on the cost of manufacture, should, in justice to the bidder, be distinctly defined.

Specifications allowing only $\frac{1}{8}$ in. above or below a standard length of 40, 41 and even 45 ft., which can be met only by cold-milling the rails, seems to be an unnecessary refinement, and would act as a hardship when applied to the output of American mills whose universal practice is hot sawing rails to length.

VIII. Drilling.

1. *American Specifications.*

The requirements which American purchasers of rails have found sufficient to obtain a satisfactory drilling of rails by American mills are described in almost all their specifications, in these words: "circular holes for splice bars shall be drilled in accordance with specifications of purchaser. They shall be accurate to drawing and dimensions furnished in every respect, and free from burrs."

2. *Foreign Specifications.*

The requirements for drilling are given in considerable detail in most foreign specifications. In some cases a less tolerance is allowed than $\frac{1}{32}$ in., which is an unnecessary refinement and cannot be regularly met in practice. American mills are specially equipped for the accurate drilling of circular holes, and hence object to the oval holes still occasionally specified.

IX. Finish.

1. *American Specifications.*

Under this heading, the requirements of the American specifications now in use specify that the rail shall be finally straightened when cold; the ends square and clean, burrs removed and the finished rail smooth on head, straight and free from injurious defects and flaws of all kinds.

2. *Foreign Specifications.*

In foreign specifications, the operations of finishing are described more in detail, and all the defects from which the rail must be free are enumerated. The British standard specifications devote very little space to these details, but probably sufficiently cover the ground, as in practice each rail is submitted to a careful surface inspection both by the manufacturer's men and by the representative ot the purchaser.

X. Branding.

1. *American Specifications.*

In American practice all branding is done on the hot rail. The name of the maker, and the month and year of manufacture, is rolled in raised letters on the web of each rail.

While the rail is still hot, the blow number is stamped on the web at least twice, and far enough from the ends to insure that the numbering can be seen after the rail is in track.

It is customary to identify "Seconds" or No. 2 rails and short rails and those of special length by painting the ends. The standard practice in America is to use white paint for No. 2 rails and green paint for "shorts."

2. *Foreign Specifications.*

(*a*) *Data to be Rolled in Raised Letter on Web of Rail.*—Foreign engineers specify considerable data to be rolled in relief on the web of each rail. Besides the maker's name, initials or other recognized mark and the month and year of rolling, the initials of the railroad are generally desired, and sometimes the weight of the rail per yard.

The British standard specifications also require a special "Brand" and the number of the "B. S." section to be rolled on the web, which shall show that the rail is of British standard section and made under the conditions of their specification. They also specify that the process by which the rails have been made shall be added, and recommend the following abbreviations:—

S. A. Siemens-Martin Acid.	B. A. Bessemer Acid.
S. B. Siemens-Martin Basic.	B. B. Bessemer Basic.

The addition of the word "steel" required by some engineers seems superfluous, as iron rails now in track can be recognized on inspection, and practically none are now rolled. In the United States the output of iron rails for 1905 was 318 tons, and in Great Britain practically *nil.*

The requirement that, in addition, a distinct mark shall be rolled on the web, said mark to be chipped off on all rejected rails, is certainly unnecessary, since it is perfectly safe to rely on the integrity of the rail-makers not to attempt to ship rails once rejected by the inspector.

(*b*) *Marking of the Blow-Number on Each Rail.*—The majority of foreign specifications require one or both ends of each rail to be stamped with the number of the blow. This stamping, of course, must be done cold, and, at best, will not be very legible; furthermore, the number cannot be seen when the rail is in track. The foreign engineer will gladly modify this to suit the American practice of mechanically stamping the blow-number, two or three times, on the web of the hot rail.

(*c*) *Additional Marking and Painting of Rails.*—Foreign specifications usually stipulate that the inspector shall brand each rail with his official stamp. This the American mills should allow, but in view of their output of 5,100 rails per 24 hr., the

inspector should arrange to do this branding without the necessity of rehandling all the rails for this special purpose.

It is fair to specify that rejected rails shall be at once so marked as to be subsequently identified during rolling, but they should not be stenciled with the word "rejected," or otherwise branded so as to render them unsaleable to other parties, should the maker so desire. The stamping of the length on each rail should be waived, as it retards loading.

The identification by paint of different colors, of short and special lengthed rails, is usual practice, but the covering of the entire rail with anti-corrosive paint, or brushing it all over with boiling linseed-oil, are requirements which so seriously retard the automatic loading-facilities of American mills that they desire to have this requirement waived, even if it can be classed as an extra.

XI. Inspection.

1. *American Specifications.*

The defining of the relations between the maker and the inspector occupy very little space in American rail-specifications.

Representatives of the purchaser are given free entry to the works and all the help they ask for; the maker gives due notice when rolling will begin, and he knows that any disputes arising will be at once settled on their merits, that all tests and inspection will be made at the mills and that there will be no serious delays in his shipment of the accepted rails.

2. *Foreign Specifications.*

The requirements of inspection found in different parts of foreign specifications are given in such detail that by the following subdivisions they can be more conveniently discussed:

(*a*) *Prior Notice of Rolling.*—This requirement is always complied with by the rail-maker, but in return he should be given permission to proceed at the time designated, if the inspector is not present.

(*b*) *Free Access to the Works.*—This privilege is always acceeded to, but foreign engineers are unnecessarily explicit in insuring that their representative shall be given all the tools, testing-appliances, gauges, templets, etc., required, and that all necessary labor and assistance shall be furnished to enable the

inspector to fulfil his duties. American mills are noted for their willingness to furnish, free of cost, every facility necessary for inspection; but in return, they have a right to ask that the inspection shall be intelligently carried out, that decisions shall be promptly made, and that they will be assured that no serious delays in manufacturing-operations shall occur during rolling, due to the absence of the inspector or his inability to follow up to his satisfaction all the requirements of the specification.

(*c*) *Cost of Inspection, Analyses and Tests to be Borne by the Manufacturer.*—The requirement that the maker shall pay all costs connected with whatever chemical analyses or physical tests by independent laboratories the inspector may demand, leaves an item of the cost of manufacture in considerable doubt. American mills object to any testing by independent laboratories and the rejection on their results, without appeal, in part because the laboratories are so far distant, and also because the samples sent may not be representative, and in some cases the results may be inaccurate. When checks by outside parties are demanded the purchaser should pay the costs.

(*d*) *Rails to be Inspected by the Manufacturer and Sorted into Lots Prior to Inspection by the Engineer.*—The provisions of foreign specifications, requiring that after the mill-inspection the finished rails shall be "sorted into lots," usually of uniform length, before examination by the representative of the purchaser, cannot be lived up to in American mills. Ample opportunity for a thorough inspection of the finished rail is given, but the re-handling necessary to comply with the above provision is impracticable and should be waived.

(*e*) *Disposition of Rejected Rails.*—The requirements that "rejected rails shall be stacked and kept apart until completion of contract" and that "no rejected rails shall be sold or consigned to scrap until the completion of the contract" are entirely unreasonable, especially when the contract is, for any reason, not completed at one continuous rolling.

(*f*) *No Appeal from Engineer's Decision.*—The foreign engineer's "written certificate" is necessary before any portion of the rails can be considered as a delivery on the contract; but even this certificate does not relieve the contractor from responsibility for replacement, and it is not obligatory on the pur-

chaser to allow any extension of time in which to deliver substituted material. Some specifications delegate "full power to the inspector to reject, without appeal," all or any part of the rolling which, in his opinion, does not comply with the specification, or which is in any way defective; others state that in case of dispute, "the engineer's decision shall be final and binding;" another specification, after stating that the material shall be made in accordance with its requirements, also prescribes that the manufacture shall be "under the control, direction and supervision of the inspector, whose instructions on all points relating to the nature and quality of materials used and workmanship executed are to be received and acted on by the makers."

While fully recognizing the purchaser's rights, as well as those assumed by his engineer, no manufacturer should enter into a contract if he felt that such clauses as the above were to be interpreted literally. The British standard specifications contain no such requirements.

(*g*) *Final Acceptance of Rails at Port of Delivery*,—To require that the final acceptance of rails shall be at the port of delivery is not a businesslike proposition; no maker of rails should be required to guarantee "to deliver said rails in perfectly good order and condition at the places of destination."

(*h*) *Rejections may be Made After Delivery*.—Some foreign engineers specify that, even after the rails had been passed by the mills and paid for, the maker must remove and replace any rails found defective by an inspection and testing instituted after delivery; it is also sometimes specified that the rails must be guaranteed for a stated period, two, five, or, in one case, ten years after having been put in track.

While it may be assumed that American makers stand ready to adjust any complaint proving that they have furnished defective material, they would naturally be unwilling to guarantee service for a certain period, because the distant port at which the rails may be delivered makes an investigation difficult, and it is unreasonable to expect them to replace rails, unless the failure in service is unquestionably the fault of the maker, a question that can be fairly determined only by representatives of both sides.

A recent committee of railroad engineers was excused from

drawing conclusions on statistics received as to the life of rails, on making the following concise and truthful report: "The life of rails is affected by many conditions, such as alignment, profile, density of traffic and speed of trains."

XII. Seconds or No. 2 Rails.

1. *American Specifications.*

The inspection of the "finish" of a rail is rigid; as already noted under this heading, the rail must be free from injurious defects and flaws of all kinds. As it is impossible to make every rail perfect, the definition of what shall constitute "seconds" or "No. 2" rails has been incorporated in American specifications, and it has become usual practice for purchasers to accept these rails for use in the main track at stations, in sidings and in yards, at a less price and in amount up to 5 per cent., and in the very heavy sections 10 per cent., in addition to the tonnage ordered. These rails are carefully identified by white paint on each end.

The standard definition of "seconds" or "No. 2" rails found in American specifications is as follows: "Rails which possess any injurious physical defects, or for any other cause, are not suitable for first quality, or No. 1 rails, shall be considered No. 2 rails."

2. *Foreign Specifications.*

No reference to "seconds" or "No. 2 rails" are found in foreign specifications. American railroads have found it to their advantage to use these cheaper rails for the purposes mentioned, and a clause covering their inspection has therefore been inserted in the proposed standard specification appended to this paper.

XIII. Proposed Standard Specification to Govern the Manufacture in American Mills of Steel Rails for Export.

In the following specification, proposed as a standard to govern the rolling of American rails for export, an effort has been made to avoid ambiguity, to bring related requirements together under one heading, to make them definite and concise, but to leave the specification flexible enough to allow an intel-

ligent inspector to use his discretion in doubtful cases without jeopardizing the duty he owes to the purchaser; it provides that his decision shall be prompt so as not to hamper unnecessarily the manufacturing-operations when the maker, in good faith, has agreed, in signing the contract, to strictly live up to the conditions required.

1. *Process of Manufacture.*

(*a*) The steel shall be of the best quality and made by the Bessemer or Siemens-Martin process.

(*b*) The materials used and the entire process of manufacture and testing shall be in strict accordance with the best standard current practice, and special care shall be taken to conform to the following instructions.

(*c*) No cracked or badly-patched molds shall be used, and the ingots shall be kept in a vertical position in the pit heating-furnaces until ready to be rolled, or until the metal in the interior has had time to solidify.

(*d*) No "bled" ingots shall be used, and no ingots from "chilled" heats rolled into first-quality rails. A "bled" ingot is one from the center of which liquid steel has escaped. A "chilled" heat is one which, because of the cooling of the steel, has to be either pricked or poured over the top of the ladle.

(*e*) Sufficient material shall be discarded or "cropped" from the top of all ingots, to insure sound rails.

(*f*) Under no circumstances shall an ingot or rail-bloom be heated so high that the cinder on it runs, when being drawn from the soaking-pit, or heating-furnace. The ingots or blooms must be evenly heated throughout their length, drawn at a uniform temperature and a uniform finishing-temperature also maintained.

2. *Chemical Composition.*

Rails of the various weights per yard specified below shall conform to the limits in chemical·composition shown in Table VII.

3. *Chemical Analyses.*

The manufacturer shall make and furnish to the representative of the engineer (or of the purchaser), before the rails rolled on each turn are ready for shipment, determinations of carbon

TABLE VII.—*Chemical Composition.*

	50 to 60 Lb.	Over 60 to 70 Lb.	Over 70 to 80 Lb.	Over 80 to 90 Lb.	Over 90 to 100 Lb.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon.......	0.30–0.50	0.35–0.45	0.35–0.45	0.40–0.50	0.40–0.50
Manganese..	0.75–0.95	0.75–0.95	0.75–0.95	0.80–0.100	0.80–0.100
Silicon.......	Not over 0.10	Not over 0.10	Not over 0.10	Not over 0.10	Not over 0.10
Phosphorus	Not over 0.10	Not over 0.10	Not over 0.10	Not over 0.10	Not over 0.10
Sulphur......	Not over 0.07	Not over 0.07	Not over 0.07	Not over 0.07	Not over 0.07

and manganese on each heat of steel; determinations of phosphorus on six heats every 12 hr., and determinations of silicon and sulphur on a sample representing each 12 hr. rolling; all said analyses to be made on drillings from a test-ingot cast when teeming each heat.

The results of these analyses shall govern, but prior to and during the rolling of the rails, the inspector shall be given all reasonable facilities to satisfy himself that the maker's method of sampling each heat is in accordance with the best standard practice, and that the various constituents of the rail-steel will be accurately determined. If so desired, but prior to rolling, the inspector may submit to the manufacturer and to an independent chemist of repute, a properly-prepared sample of rail-steel for joint analysis, with a view of proving the accuracy of the analyses which will be furnished daily, from the mill-laboratory, when rolling begins; the expense of this joint-analysis to be equally divided between the contractor and purchaser.

If, during rolling, the accuracy of any report from the steel-works laboratory on a heat of steel is promptly questioned, and not immediately settled to the inspector's satisfaction by a check analysis at the mill, the inspector will be furnished an identified sample of drillings from the test-ingot, the analysis of which, by an independent chemist of repute, must be furnised and the dispute settled before the rails from said heat are ready for shipment. The purchaser shall pay the cost of any and all such check analyses.

If requested, the manufacturer shall furnish, on an average sample of the tonnage rolled, a determination of arsenic, copper, or other constituents, incidently present in determinable quantities.

4. *Impact Test.*

From either end of a rail, from every other heat of steel, shall be cut, at the hot saws, a piece from 4 to 6 ft. long, which shall be distinctly stamped with the heat-number, as directed by the representative of the engineer (or of the purchaser), and the piece set aside on skids to cool. As soon as cool, it shall be placed, head upwards, on the supports of the standard American rail drop-testing machine, described below, and the various sections must withstand, without fracture, one blow of the 2,000-lb. tup, from the height specified in Table VIII. The report of the drop-test shall include a record of the atmospheric temperature at the time the tests are made, and, if necessary, due allowance shall be made for rails tested at or below freezing-temperature.

TABLE VIII.—*Falling Weight Test.*

Weight of Rail.	Height of Drop.	Range in Carbon.
Pounds Per Yard.	Feet.	Per Cent.
50, up to and including 60.........	16	0.30–0.40
More than 60, up to and including 70.........	17	0.35–0.45
More than 70, up to and including 80.........	18	0.35–0.45
More than 80, up to and including 90.........	19	0.40–0.50
More than 90, up to and including 100.........	20	0.40–0.50

With regard to a provision for retest, in case the pieces of rail selected to represent the heat fails under test, two other rails will be selected and similar lengths cut therefrom, or crop-ends of sufficient length already cut from two other rails of the same heat may be used. If either of these pieces or crop-ends fail, all the rails of the heat which they represent will be rejected, but if both these latter tests meet the requirements, all the rails of the heat will be accepted.

In case the rails from two successive tested heats are rejected for failure to meet the requirements of the drop-test, the intermediate heat will be tested as above described.

The acceptance or rejection of all the rails from any heat will depend upon the result of the drop-test thereof.

5. *Drop-Test Machine.*

Prior to making any impact tests, the inspector shall be given opportunity to satisfy himself that the drop-testing machine, in

its essential features, complies with the following requirements: the weight of the tup shall be 2,000 lb.; the radius of its striking face 5 in.; the weight of the anvil block shall be amply sufficient to insure rigidity, and, moreover, it shall rest on a solid masonry foundation. The iron or steel supports for the rails shall be rounded to a radius of 5 in., set 3 ft. apart between centers, and shall be firmly secured to the anvil block. The tup shall be so arranged that it can be conveniently dropped from any specified height.

6. *Section.*

Before the general manufacture of the rails is commenced, the manufacturer shall, if required by the engineer (or by the purchaser), supply two sets of templets, internal and external, made of approved material. These templets, engraved as specified in the contract, shall be submitted to the engineer (or to the purchaser) for his approval, and at the commencement of rolling the engineer will have a competent person present to approve of the section.

The rails shall be of uniform section throughout, and shall conform, as accurately as possible, to the approved templet, consistent with paragraph No. 7 relative to specified weight. To allow for the unavoidable wear of the rolls, a variation in height of $\frac{1}{64}$ in. less and $\frac{1}{32}$ in. greater than the specified height will be permitted. A perfect fit of the fish-plates, however, shall be maintained at all times.

7. *Weight.*

The weight of the rails shall be maintained as nearly as possible, after complying with paragraph No. 6, to that specified in the contract. A variation of 0.5 per cent. for an entire order will be allowed. The manufacturer shall weigh one rail each hour during the entire rolling.

Rails shall be accepted and paid for according to actual weight.

8. *Length.*

The standard length of rails shall be 33 ft. Ten per cent. of the entire order, if made, will be accepted in shorter lengths, varying by even feet down to 27 ft. A variation of 0.25 in. longer or shorter than the standard length will be allowed.

This allowable variation shall be $\frac{3}{8}$ in. longer or shorter for rails over standard length.

When rails of special lengths, slightly shorter than 33 ft., are ordered for curves, they will not be counted in the allowable percentage of short rails.

9. *Drilling.*

Circular holes for fish-bolts shall be drilled through the web, from the solid, at each end of the rails and in strict accordance to the specification. They shall conform accurately to the drawing and dimensions furnished in every respect, must be clean and square with the web, and left without burrs on either side.

Should any of the holes vary from the correct size or position more than $\frac{1}{32}$ in., the rails in question will be liable to rejection.

10. *Finish.*

Rails shall be straight in line and surface when finished; the straightening being carefully done while cold; smooth on head, sawed square at ends (variation to be not more than $\frac{1}{32}$ in.), and, prior to shipment, shall have the burr occasioned by the saw cutting carefully chipped and filed off, particularly under the head and on top of the flange; the ends must be clean. The rails are to be free from injurious defects and flaws of all kinds.

11. *Branding.*

The maker's name, initials or other recognized mark, the month and year of manufacture and the initials of the railroad, shall be rolled in raised letters on the side of the web. If specially desired, the weight of the rail per yard will be added.

The heat-number shall be plainly stamped on the web of each rail while hot, in at least two places and at a sufficient distance from the ends, so that it will not be subsequently covered by the fish-plate.

All rails definitely rejected shall be at once marked in such a distinctive manner as will enable the inspector to readily identify them, but not so as to render them unsaleable to other parties.

Both ends of all "seconds" or No. 2 rails to be painted white. Both ends of all short lengths first quality or No. 1

rails to be painted green. Special length rails for curves to be painted red.

12. *Inspection.*

The manufacturer shall give to the engineer (or the purchaser), or his inspector, if so instructed, a reasonable notice, in writing, before rolling shall be begun, and similar written notices in advance of each resumption of rolling, in case the order is not filled at one continuous rolling. Should the maker fail to give said notice, all rails rolled in the absence of the duly authorized representative may be rejected as part of the contract. The party thus notified shall, in turn, give written notice to the manufacturer of his intention to be present, or permission to proceed at the time designated by the maker.

Authorized representatives shall have free access to the works of the manufacturer at all times when the contract is being filled, and shall have, free of cost, all reasonable facilities afforded by the maker to satisfy them that the finished rails are furnished in accordance with the terms of these specifications; the inspection shall, therefore, be conducted so as to cause no serious delays in the processes of manufacture.

Rails will be passed upon individually or by heats, according to the character of the requirements specified. Rejected rails to become at once the property of the maker.

All tests and inspection shall be made at the place of manufacture, and the engineer, or his representative at the mill, shall be empowered to give the necessary written certificates of acceptance to the manufacturer, in such a manner as not to cause delays in the shipment of inspected rails.

13. "*Seconds*" *or No.* 2 *Rails.*

Rails which possess any injurious defects, or which from any other cause are not suitable for first quality or No. 1 rails, shall be considered as "seconds" or No. 2 rails.

They shall not have flaws in their heads of more than 0.25 in., or in the flange of more than 0.5 in. in depth, and, in the judgment of the inspector, these shall not be so numerous or of such a character as to render them unfit for recognized No. 2 rail uses, such as in the main track at stations, in sidings and in yards.

The ends of No. 2 rails shall be painted white, and they shall

have two prick-punch marks on the side of the web near the blow number brand, and placed so as not to be covered by the fish-plates.

No. 2 rails will be accepted up to 5 per cent. of the whole order.

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SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Lime-Roasting of Galena.

BY W. R. INGALLS, NEW YORK, N. Y.

(London Meeting, July, 1906.)

DURING the last two years, and especially during the last six months, a number of important articles upon the new methods for the desulphurization of galena have been published in the technical periodicals, particularly in the *Engineering and Mining Journal* and in *Metallurgie.* I proposed for these methods the type-name of "lime-roasting" of galena as a convenient metallurgical classification,[1] and this term has found some acceptance. The articles referred to have shown the great practical importance of these new processes, and the general recognition of their metallurgical and commercial value which has already been accorded to them. It is my present purpose to review broadly the changes developed by them in the metallurgy of lead, in which connection it is necessary to refer briefly to the previous state of the art.

The elimination of the sulphur-content of galena has been always the most troublesome part of the smelting-process, being both costly in the operation and wasteful of silver and lead. Previous to the introduction of the Huntington-Heberlein process at Pertusola, Italy, it was effected by a variety of methods. In the treatment of non-argentiferous galena concentrate, the smelting was done by the roast-reduction method (roasting in reverberatory furnace and smelting in blast-furnace); the roast-reaction method, applied in reverberatory furnaces; and the roast-reaction method, applied in Scotch hearths.[2] Precipitation-smelting, simple, had practically gone out of use, although its reactions enter into the modern blast-furnace practice, as do also those of the roast-reaction method.

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[1] *Engineering and Mining Journal,* September 2, 1905.

[2] This term is inexact, because the hearths employed in the United States are not strictly "Scotch hearths," but they are commonly known as such, wherefore my use of the term.

In the treatment of argentiferous lead-ores, a combination of the roast-reduction, roast-reaction and precipitation-methods had been developed. Ores low in lead were still roasted, chiefly in hand-worked reverberatories (the mechanical furnaces not having been proved well adapted to lead-bearing ores), while the high loss of lead and silver in sinter- or slag-roasting of rich galenas had caused those processes to be abandoned, and such ores were charged raw into the blast-furnace, the part of their sulphur which escaped oxidation therein reappearing in the form of matte. In the roast-reduction smelting of galena alone, however, there was no way of avoiding the roasting of the whole, or at least a very large percentage of the ore, and in this roasting the ore had necessarily to be slagged or sintered in order to eliminate the sulphur to a satisfactory extent. This is exemplified in the treatment of the galena concentrate of southeastern Missouri at the present time.

Until the two new Scotch-hearth plants at Alton and Collinsville, Ill., were put in operation, the three processes of smelting the southeastern Missouri galena were about on an equal footing. Their results per ton of ore containing 65 per cent. of lead were approximately as follows. (Percentages of lead in Missouri practice are based on the wet assay; among the silver-lead smelters of the West the fire-assay is still generally employed.)

Method.	Cost.	Extraction. Per Cent.
Reverberatory,	$6.50–$7.00	90–92
Scotch-hearth,	$5.75–$6.50	87–88
Roast-reduction,	$6.00–$7.00	90–92

The new works employ the Scotch-hearth process, with baghouses for the recovery of the fume, which previously was the weak point of this method of smelting. This improvement did not originate at either Alton or Collinsville, having been previously in use at the works of the Missouri Smelting Company at Cheltenham, St. Louis, but the idea originated from the practice of the Picher Lead Company, of Joplin, Mo. This improvement led to a large increase in the recovery of lead, so that the entire extraction is now approximately 98 per cent. of the content of the ore, while, on the other hand, the cost of smelting per ton of ore has been reduced through the increased size of these plants and the introduction of improved means for

handling ore and material. The practice of these works represents the highest efficiency yet obtained in this country in the smelting of high-grade galena-concentrate, and probably it can not be equalled even by the Huntington-Heberlein and similar processes. The Scotch-hearth and bag-house process is therefore the one of the older methods of smelting which will survive.

In the other methods of smelting, a large proportion of the cost is involved in the roasting of the ore, which amounts in hand-worked reverberatory furnaces to from $2 to $2.50 per ton. Also, the larger proportion of the loss of metal is suffered in the roasting of the ore, this amounting to from 6 to 8 per cent. of the metal content of such ore as is roasted. The loss of lead in the combined process of treatment depends upon the details of the process. The chief advantage of lime-roasting in the treatment of this class of ore is in the higher extraction of metal which it affords. This should rise to 98 per cent. That figure, indeed, has been surpassed in operations on a large scale, extending over a considerable period.

In the treatment of the argentiferous ores of the West, different conditions enter into the consideration. In the working of those ores, the present practice is to roast only those which are low in lead, and charge raw into the blast-furnace the rich galenas. The cost of roasting is from $2 to $2.50 per ton; the cost of smelting is about $2.50 per ton. On the average about 0.4 ton of ore has to be roasted for every ton that is smelted. The cost of roasting and smelting is therefore about $3.50 per ton. In good practice the recovery of silver is about 98 per cent. and of lead about 95 per cent., reckoned on the fire-assay.

In the treatment of these ores, the lime-roasting process offers several advantages. It may be performed at less than the cost of ordinary roasting. (This refers especially to the Savelsberg process.) The loss of silver and lead during the roasting is reduced to insignificant proportion. The sulphide-fines which must be charged raw into the blast-furnace are eliminated, inasmuch as they can be efficiently desulphurized in the lime-roasting pots without significant loss; all the ore to be smelted in the blast-furnace, therefore, can be delivered to it in lump form, whereby the speed of the blast-furnace is increased and the wind-pressure required is decreased. Finally, the percent-

age of sulphur in the charge is reduced, producing a lower matte-fall, or no matte-fall whatever, with consequent saving in expense of retreatment. In the case of a new plant, the first cost of construction and the ground-space occupied are materially reduced. Before discussing more fully the extent and nature of these savings, it is advisable to point out the differences among the three processes of lime-roasting that have already come into practical use.

In the Huntington-Heberlein process, the ore is mixed with suitable proportions of limestone or silica (or quartzose ore), and is then partially roasted, say, to reduction of the sulphur to one-half. The roasting is done at a comparatively low temperature, and the loss of metals is consequently small. The roasted ore is dampened and allowed to cool. It is then charged into a hemispherical cast-iron pot, with a movable hood which covers the top and conveys off the gases. There is a perforated grate in the bottom of the pot, on which the ore rests, and air is introduced through a pipe entering the bottom of the pot, under the grate. A small quantity of red-hot calcines from the roasting furnaces is thrown on the grate to start the reaction; a layer of cold, semi-roasted ore is put upon it, the air-blast is turned on and reaction begins, which manifests itself by the copious evolution of sulphur-fumes. These consist chiefly of sulphur dioxide, but they contain more or less trioxide, which is evident from the solution of copperas that trickles from the hoods and iron smoke-pipes, wherein the moisture condenses. As the reaction progresses, and the heat creeps up, more ore is introduced, layer by layer, until the pot is full. Care is taken by the operator to compel the air to pass evenly and gently through the charge, wherefore he is watchful to close blow-holes which develop in it. At the end of the operation, which may last from 4 to 18 hr., the ore becomes red hot at the top. The hood is then pushed up, and the pot is turned on its trunnions, by means of a hand-operated wheel and worm-gear, until the charge slides out, which it does as a solid, semi-fused cake. The pot is then turned back into position. Its design is such that the air-pipe makes automatic connection, a flanged pipe, cast with the pot, settling upon a similarly flanged pipe communicating with the main, a suitable gasket serving to make a tight joint. The pots are set at an elevation of about 12 ft. above the

ground, so that when the charge slides out the drop will break it up to some extent; moreover, it is caused to fall on a wedge, or similar contrivance, to assist the breakage. After cooling, it is further broken up to furnace-size by wedging and sledging; the lumps are forked out, and the fines screened and returned to a subsequent charge for completion of their desulphurization.

The Savelsberg process differs from the Huntington-Heberlein in respect to the preliminary roasting, which, in the Savelsberg process, is omitted, the raw ore, mixed with limestone and silica, being charged directly into the converter. The Savelsberg converter is supported on a truck, instead of being fixed in position, but otherwise its design and management are quite similar to those of the Huntington-Heberlein converter. In neither case are there any patents on the converters. The patents are on the processes. In view of the litigation that has already been commenced between their respective owners, it is interesting to examine the claims.

The Huntington-Heberlein patent (U. S. No. 600,347, issued March 8, 1898, applied for December 9, 1896) has the follow-lowing claims:—

1. The herein-described method of oxidizing sulphide-ores of lead preparatory to reduction to metal, which consists in mixing with the ore to be treated an oxide of an alkaline-earth metal, such as calcium oxide, subjecting the mixture to heat in the presence of air, then reducing the temperature, and finally passing air through the mass to complete the oxidation of the lead, substantially as and for the purpose set forth.

2. The herein-described method of oxidizing sulphide-ores of lead preparatory to reduction to metal, which consists in mixing calcium oxide or other oxide of an alkaline-earth metal with the ore to be treated, subjecting the mixture, in the presence of air, to a bright-red heat (about 700° C.), then cooling down the mixture to a dull-red heat (about 500° C.), and finally forcing air through the mass until the lead-ore, reduced to an oxide, fuses, substantially as set forth.

3. The herein-described method of oxidizing lead sulphide in the preparation of the same for reduction to metal, which consists in subjecting the sulphide to a high temperature in the presence of an oxide of an alkaline-earth metal, such as calcium oxide, and oxygen, and then lowering the temperature, substantially as set forth.

Adolf Savelsberg, in U. S. Patent No. 755,598 (issued March 22, 1904, applied for December 18, 1903), claims:—

1. The herein-described process of desulphurizing lead-ores, which consists in mixing raw ore with limestone and then subjecting the mixture to the simultaneous application of heat and a current of air in sufficient proportions to substantially complete the desulphurization in one operation, substantially as described.

2. The herein-described process of desulphurizing lead-ores, which process consists in first mixing the ores with limestone, then moistening the mixture, then filling it without previous roasting into a chamber, then heating it and treating it by a current of air, as and for the purpose described.

3. The herein-described process of desulphurizing lead-ores, which consists in mixing raw ores with limestone, then filling the mixture into a chamber, then subjecting the mixture to the simultaneous application of heat and a current of air in sufficient proportions to substantially complete the desulphurization in one operation, the mixture being introduced into the chamber in partial charges introduced successively at intervals during the process, substantially as described.

4. The herein-described process of desulphurizing lead-ores, which process consists in first mixing the ores with limestone, then moistening the mixture, then filling it without previous roasting into a chamber, then heating it and treating it by a current of air, the mixture being introduced into the chamber in partial charges introduced successively at intervals during the process, as and for the purpose described.

5. The herein-described process of desulphurizing lead-ores, which process consists in first mixing the ores with sufficient limestone to keep the temperature of the mixture below the melting-point of the ore, then filling the mixture into a chamber, then heating said mixture and treating it with a current of air, as and for the purpose described.

6. The herein-described process of desulphurizing lead-ores, which process consists in first mixing the ores with sufficient limestone to mechanically separate the particles of galena sufficiently to prevent fusion, and to keep the temperature below the melting-point of the ore by the liberation of carbon dioxide, then filling the mixture into a chamber, then heating said

mixture and treating it with a current of air, as and for the purpose described.

The Carmichael-Bradford process differs from the Savelsberg by the treatment of the raw ore mixed with gypsum instead of limestone, and differs from the Huntington-Heberlein both in respect to the use of gypsum and the omission of the preliminary roasting. The Carmichael-Bradford process has not been threatened with litigation, so far as I am aware. The claims of its original patent read as follows:[3]—

1. The process of treating mixed sulphide-ores, which consists in mixing with said ores a sulphur compound of a metal of the alkaline earths, starting the reaction by heating the same, thereby oxidizing the sulphide and reducing the sulphur compound of the alkali metal, passing a current of air to oxidize the reduced sulphur compound of the metal of the alkalies preparatory to acting upon a new charge of sulphide-ores, substantially as and for the purpose set forth.

2. The process of treating mixed sulphide-ores, which consists in mixing calcium sulphate with said ores, starting the reaction by means of heat, thereby oxidizing the sulphide-ores, liberating sulphurous-acid gas, and converting the calcium sulphate into calcium sulphide, and oxidizing the calcium sulphide to sulphate preparatory to treating a fresh charge of sulphide-ores, substantailly as and for the purpose set forth.

The process described by W. S. Bayston, of Melbourne (Australian Patent No. 2,862), appears to be identical with that of Savelsberg.

Irrespective of the validity of the Savelsberg and Carmichael-Bradford patents, and without attempting to minimize the ingenuity of their inventors and the importance of their discoveries, it must be conceded that the merit for the invention and introduction of lime-roasting of galena belongs to Thomas Huntington and Ferdinand Heberlein. The former is an American, and this is the only claim that the United States can make to a share in this great improvement in the metallurgy of lead. It is to be regretted, moreover, that of all the important lead-smelting countries of the world, America has been the most backward in adapting it.

[3] A. D. Carmichael, U. S. Patent No. 705,904, July 29, 1902.

The details of the three processes and the general results accomplished by them have been rather fully described in a series of articles recently published in the *Engineering and Mining Journal.* There has been, however, comparatively little discussion as to costs; and, unfortunately, the data available for analysis are extremely scanty, due to the secrecy with which the Huntington-Heberlein process, the most extensively exploited of the three, has been veiled. Nevertheless, I may attempt an approximate estimation of the various details, taking the Huntington-Heberlein process as the basis.

The ore, limestone and silica are crushed to pass a 4-mesh screen. This is about the size to which it would be necessary to crush as preliminary to roasting in the ordinary way, wherefore the only difference in cost is the charge for crushing the limestone and silica, which in the aggregate may amount to one-sixth of the weight of the raw sulphide, and may consequently add 2 to 2.5c. to the cost of treating a ton of ore. The mixing of ore and fluxes may be costly or cheap, according to the way of doing it. If done in a rational way it ought not to cost more than 10c. per ton of ore, and may come to less. The delivery of the ore from the mixing-house to the roasting-furnaces ought to be done entirely by mechanical means, at insignificant cost.

The Heberlein roasting-furnace, which is used in connection with the "H.-H." process, is simply an improvement on the old Brunton calciner—a circular furnace, with revolving hearth. The construction of this furnace, according to American designs, is excellent. The hearth is 26 ft. in diameter; it is revolved at slow speed, and requires about 1.5 h.p. A flange at the periphery of the hearth dips into sand in an annular trough, thus shutting off air from the combustion-chamber, except through the ports designed for its admittance. The mechanical construction of the furnace is workmanlike, and the mechanism under the hearth is easy of access and comfortably attended to.

A 26-ft. furnace roasts about 80,000 lb. of charge per 24 hr. In dealing with an ore containing from 20 to 22 per cent. of sulphur, the latter is reduced to about 10 or 11 per cent., the consumption of coal being about 22.5 per cent. of the weight of the charge. The hearth-efficiency is about 150 lb. per sq. ft., which, in comparison with ordinary roasting, is high. The coal-

consumption, however, is not corresponding low. Two furnaces can be managed by one man per 8 hr. shift. On the basis of 80 tons of charge ore per 24 hr., the cost of roasting should be approximately as follows:

Labor: 3 men at $2.50, . . .	$ 7.50
Coal: 18 tons at $2, . . .	36.00
Power, ...	3.35
Repairs, ...	3.35
Total, ...	$50.20 for 80 tons, or 63c. per ton.

In the above estimate repairs have been reckoned at the same amount as is experienced with Brückner cylinders, and the cost of power has been allowed for with fair liberality. The estimated cost of 63c. per ton is comparable with the $1.10 to $1.45 per ton, which is the result of roasting in Brückner cylinders in Colorado, reducing the ore to from 4.5 to 6 per cent. of sulphur.

The Heberlein furnace is built up to considerable elevation above the ground-level, externally somewhat resembling the Pearce turret-furnace. This serves two purposes: (1) it affords ample room under the hearth for attention to the driving mechanism; and (2) it enables the ore to be discharged by gravity into suitable hoppers, without the construction of subterranean gang-ways. The ore discharges continuously from the furnace, at dull-red heat, into a brick bin, wherein it is cooled by a water-spray. Periodically, a little ore is diverted into a side-bin, in which it is kept hot for starting a subsequent charge in the converter.

The cooled ore is conveyed from the receiving-bins at the roasting-furnaces to hopper-bins above the converters. If the tramming be done by hand the cost, with labor at 25c. per hr., may be approximately 12.5c. per ton of ore, but this should be capable of considerable reduction by mechanical conveyance.

The converters are hemispherical pots of cast-iron, 9 ft. in diameter at the top and about 4 ft. in depth. They are provided with a circular, cast-iron grate, which is 0.75 in. thick and 6 ft. in diameter, and is set and secured horizontally in the pot. This grate is perforated with holes 0.75 in. in diameter, 2 in. apart, center to center, and is similar to the Wetherill grate employed in zinc oxide manufacture. The pot itself is

about 2.5 in. thick at the bottom, thinning to about 1.5 in. at the rim. It is supported on trunnions, and is geared for convenient turning by hand. The blast-pipe which enters the pot at the bottom is 6 in. in diameter.

Two roasting-furnaces and six converters are rated nominally as a 90-ton plant. This rating, however, is considerably in excess of the actual capacity, at least on certain ores. The time required for desulphurization in the converter apparently depends a good deal upon the character of the ore. The six converters may be arranged in a single row, or in two rows of three in each. They are set so that the rim of the pot, when upright, is about 12 ft. above the ground-level. A platform gives access to the pots. One man per shift can attend to two pots. His work consists in charging them, which is done by gravity, spreading out the charge evenly in the pot, closing any blow-holes which may develop, and at the end of the operation raising the hood (which covers the pot during the operation) and dumping the pot. The work is easy. The conditions under which it is done are comfortable, both as to temperature and atmosphere. Reports have shown a great reduction in liability to lead poisoning in the works where the "H.-H." process has been introduced.

A new charge is started by kindling a small wood or coal fire on the grate, then throwing in a few shovelfuls of hot calcines, and finally dropping in the regular charge of damp ore (plus the fluxes previously referred to). The charge is introduced in stages, successive layers being dropped in and spread out as the heat rises. At the beginning the blast is very low—about 2 oz. It is increased as the height of the ore in the pot rises, finally attaining about 16 oz. The operation goes on quietly, the smoke rising from the surface evenly and gently, precisely as in a well-running blast-furnace. While the charge is still black on top, the hand can be held with perfect comfort inside of the hood, immediately over the ore. This explains, of course, why the volatilization of silver and lead is insignificant. There is, moreover, little or no loss of ore as dust, because the ore is introduced damp, and the passage of the air through it is at low velocity. In the interior of the charge, however, there is high temperature (evidently much higher than has been stated in some descriptions), as will be shown further

on. The conditions in this respect appear to be analogous to those of the blast-furnace, which, though smelting at a temperature of about 1,200° C. at the area of the tuyeres, suffers only a slight loss of silver and lead by volatilization.

At the end of the operation in the "H.-H." pot, the charge is dull red at the top, with blow-holes, around which the ore is bright red. Imperfectly-worked charges show masses of well-fused ore, surrounded by masses of only partly altered ore, a condition which may be ascribed to the irregular penetration of air through the charge, affording good evidence of the important part which air plays in the process. A properly-worked charge is tipped out of the pot as a solid cake, which, in falling to the ground, breaks into a few large pieces. As they break, it appears that the interior of the charge is bright red all through, and there is a little molten slag which runs out of cavities, presumably spots where the chemical action has been most intense. When cold, the thoroughly desulphurized material has the appearance of slag-roasted galena. Prills of metallic lead are visible in it, indicating reaction between lead sulphide and lead sulphate.

The columns of the structure supporting the pots should be of steel, since fragments of the red-hot ore dumped on the ground are likely to fall against them. To hasten the cooling of the ore, water is sometimes played on it from a hose. This is bad, since some is likely to splash into the still inverted pot, leading to cracks. The cracked pots at certain works appear to be due chiefly to this cause, in the absence of which the pots ought to last a long time, inasmuch as the conditions to which they are subjected during the blowing-process are not at all severe. When the ore is sufficiently cold it is further broken up, first by driving in wedges, and finally by sledging down to pieces of orange size, or what is suitable for the blast-furnace. These are forked out, leaving the fine ore, which comes largely from the top of the charge, and is therefore only partially desulphurized. The fines are, therefore, retreated with a subsequent charge. The quantity is not excessive; it may amount to 7 or 8 per cent. of the charge.

The breaking up of the desulphurized ore is one of the problems of the process, the necessity being the reduction of several large pieces of fused, or semi-fused, material weighing two or

three tons each. When done by hand only, as is usually (perhaps always) the practice, the operation is rather expensive. It would appear, however, to be not a difficult matter to devise some mechanical aids for this process—perhaps to make it entirely mechanical. When done by hand, a six-pot plant requires six men per shift sledging and forking. With 8-hr. shifts, this is 18 men for the breaking of about 60 tons of material, which is about 3⅓ tons per man per 8 hr. With labor at 25c. per hour, the cost of breaking the fused material comes to 60c. per ton. It may be remarked, for comparison, that in breaking ore as it ordinarily comes, coarse and fine together, a good workman would normally be expected to break from 5 to 5.5 tons in a shift of 8 hr.

The ordinary charge for the standard converter is about 8 tons (16,000 lb.) of an ore weighing 166 lb. per cu. ft. With a heavier ore, like a high-grade galena, the charge would weight proportionately more. The time of working off a charge is decidedly variable. Accounts of the operation of the process in Australia tell of charge-workings in from 3 to 5 hr., but this does not correspond with the results reported elsewhere, which specify times of from 12 to 18 hr. Assuming an average of 16 hr., which was the record of one plant, six converters would have capacity for about 72 tons of charge per 24 hr., or about 58 tons of ore, the ratio of ore to flux being 4 : 1. The loss in weight of the charge corresponds substantially to the replacement of sulphur by oxygen, and the expulsion of carbon dioxide. The finished charge contains, on the average, from 3 to 5 per cent. of sulphur. This is about the same as the result achieved in good practice in roasting lead-bearing ores in hand-worked reverberatory furnaces; but curiously the "H.-H." product, in some cases at least, does not yield any matte, to speak of, in the blast-furnace,—the product delivered to the latter being evidently in such condition that the remaining sulphur is almost completely burned off in the blast-furnace. This is an important saving effected by the process. In calculating the value of an ore, sulphur is commonly debited at the rate of 25c. per unit, which represents approximately the cost of handling and reworking the matte resulting from it. The practically complete elimination of matte-fall rendered possible by the "H.-H." process, however, may not be an unmixed bless-

ing. There may be, for example, a small formation of lead sulphide which causes trouble in the crucible and lead-wall; and results in furnace difficulties and the presentation of a vexatious between-product.

It may now be attempted to summarize the cost of the converting process. Assuming the case of an ore assaying lead, 50; of iron, 15; sulphur, 22; silica, 8, and alumina, etc., 5 per cent., let it be supposed that it is to be fluxed with pure limestone and pure quartz, with the aim to make a slag containing silica, 30; ferrous oxide, 40; and lime, 20 per cent. A ton of ore will make, in round numbers, 1,000 lb. of slag, and will require 344 lb. of limestone and 130 lb., or, we may say roughly, one ton of flux must be added to four tons of ore, wherefore the ore will constitute 80 per cent. of the charge. In reducing the charge to 3 per cent. of sulphur it will lose ultimately through expulsion of sulphur and carbon dioxide (of the limestone) about 20 per cent. in weight, wherefore the quantity of material to be smelted in the blast-furnace will be practically equivalent to the raw sulphide-ore in the charge for the roasting-furnaces, but in the roasting-furnace the charge is likely to gain weight, because of the formation of sulphates. Taking the charge, which I have assumed above, and reckoning that as it came from the roasting-furnace it will contain 10 per cent. of sulphur, all in the form of sulphate, either of lead or of lime, and that the iron be entirely converted to ferric oxide, in spite of the expulsion of the carbon dioxide of the limestone and the combustion of a portion of the sulphur of the ore as sulphur dioxide, the charge will gain in weight in the ratio of 1:1.18. This, however, is too high, inasmuch as a portion of the sulphur will remain as sulphide, while a portion of the iron may be as ferrous oxide. The actual gain in weight will consequently be probably not more than one-tenth. The theoretical calculation on page 694 will illustrate the changes.

It may be assumed that for every ton of charge (containing about 80 per cent. of ore) there will be 1.1 ton of material to go to the converter, and that the product of the latter will be 0.9 of the weight of the original charge of raw material.

Each converter requires 400 cu. ft. of air per min. The blast-pressure is variable, as different pots are always at different stages of the process; but assuming the maximum of 16 oz. pres-

	Raw Charge.		Semi-Roasted Charge.		Finished Charge.
ore	1,000 lb. Pb.	ore	1,154 lb. PbO.	ore	1,154 lb. PbO.
	300 lb. Fe.		428 lb. Fe_2O_3.		428 lb. Fe_2O_3 (?)
	160 lb. SiO_2.		160 lb. SiO_2.		160 lb. SiO_2.
	100 lb. Al_2O_3, etc.		100 lb. Al_2O_3, etc.		100 lb. Al_2O_3, etc.
	440 lb. S.		300 lb. S.		68 lb. S.
flux	130 lb. SiO_2.	flux	130 lb. SiO_2.	flux	130 lb. SiO_2.
	344 lb. $CaCO_3$.		193 lb. CaO.		193 lb. CaO.
	....		450 lb. O.		....
	2,474 lb.		2,915 lb.		2,233 lb.
			10 per cent. S.		3 per cent. S.

Ratios :

2,474 : 2,915 : : 1 : 1.18.
2,915 : 2,233 : : 1 : 0.76⅔.
2,474 : 2,233 : : 1 : 0.90.

sure, with a blast main of sufficient diameter (at least 15 in.) and the blower reasonably near the battery of pots, the total requirement is 21 h.p. The cost of converting will be approximately as follows:

Labor:	3 foremen at $3.20, .	$ 9.60
	9 men at 2.50, . .	22.50
Power:	21 h.p. at 30c., . .	6.30
Supplies, repairs and renewals .		5.00
Total, ...		$43.40 = 60c. per ton of charge.

The cost of converting is, of course, reduced directly as the time is reduced. The above estimate is based on unfavorable conditions as to time required for working a charge.

The total cost of treatment from the initial stage to the delivery of the desulphurized ore to the blast-furnaces, will be, per 2,000 lb. of charge, approximately as follows:

Crushing, 1.0 ton at 10c., ...	$0.10
Mixing, 1.0 ton at 10c., ...	0.10
Roasting, 1.0 ton at 63c., ...	0.63
Delivering, 1.1 ton to converters at 12c., ...	0.13
Converting, 1.1 ton at 60c., ...	0.66
Breaking, 0.9 ton at 60c., ...	0.54
Total, ...	$2.15

The cost per ton of ore will be 2.16 ÷ 0.80 = $2.70. Making allowance for the crushing of the ore, which is not ordinarily included in the cost of roasting, and possibly some over-

estimates, it appears that the cost of desulphurization by this method, under the conditions assumed in this paper, is rather higher than in good practice with ordinary hand-worked furnaces, but it is evident that the cost can be reduced to approximately the same figure by introduction of improvements, as, for example, in breaking the desulphurized ore, and by shortening the time of converting, which is possible in the case of favorable ores. The chief advantage, however, must be in the further stage of the smelting. As to this, there is the evidence that the Broken Hill Proprietary Co., after the introduction of the Huntington-Heberlein process, was able to smelt the same quantity of ore in seven furnaces that formerly required thirteen. A similar experience is reported at Friedrichshütte, Silesia.

This increase in the capacity of the blast-furnace is due to three things: (1) In delivering to the furnace a charge containing a reduced percentage of fine ore, the speed of the furnace is increased, *i.e.*, more tons of ore can be smelted per sq. ft. of hearth-area. (2) There is less roasted matte to go into the charge. (3) Under some conditions the percentage of lead in the charge can be increased, reducing the quantity of gangue that must be fluxed.

It is difficult to generalize the economy that is effected in the blast-furnace process, since this must necessarily vary within wide limits because of the difference in conditions. An increase of from 60 to 100 per cent. in blast-furnace capacity does not imply a corresponding reduction in the cost of smelting. The fuel-consumption per ton of ore remains the same. There is saving in the power requirements, because the smelting can be done with a lower blast-pressure; also, a saving in the cost of reworking matte. Moreover, there will be a saving in other labor, in so far as portions thereof are not already performed at the minimum cost per ton. The net result under American conditions of silver-lead smelting can be determined closely only by extensive operations. That there will be an important saving, however, there is no doubt.

The cost of smelting a ton of charge at Denver and Pueblo, exclusive of roasting and general expense, is about \$2.50, of which about \$0.84 is for coke and \$1.66 for labor, power and supplies. General expense amounts to about \$0.16 additional.

If it should prove possible to smelt in a given plant 50 per cent. more ore than at present without increase in the total expense, except for coke, the saving per ton of charge would be 70c. That is not to be expected, but the half of it would be a satisfactory improvement. With respect to sulphur in the charge, the cost is commonly reckoned at 25c. per unit. As compared with a charge containing 2 per cent. of sulphur there would be a saving rising toward 50c. per ton as the maximum. It is reasonable, therefore, to reckon a possible saving of 75c. per ton of charge in silver-lead smelting, no saving in the cost of roasting, and an increase of about 3 per cent. in the extraction of lead, and perhaps 1 per cent. in the extraction of silver, as the net results of the application of the Huntington-Heberlein process in American silver-lead smelting.

On a charge averaging 12 per cent. of lead and 33 oz. of silver per ton, an increase of 3 per cent. in the extraction of lead, and 1 per cent. in the extraction of silver would correspond to 25c. and 35c. respectively, reckoning lead at 3.5c. per lb., and silver at 60c. per oz. In this, however, it is assumed that all lead-bearing ores will be desulphurized by this process, which practically will hardly be the case. A good deal of pyrites, containing only a little lead, will doubtless continue to be roasted in Brückner cylinders, and other mechanical furnaces, which are better adapted to the purpose than are the lime-roasting pots. Moreover, a certain proportion of high-grade lead-ore, which is now smelted raw, will be desulphurized outside of the furnace, at additional expense. It is comparatively simple to estimate the probable benefit of the Huntington-Heberlein process in the case of smelting-works which treat principally a single class of ore, but in such works as those in Colorado and Utah, which treat a wide variety of ores, we must anticipate a combination process, and await results of experience to determine just how it will work out. It should be remarked, moreover, that my estimates do not take into account the royalty on the process, which is an actual debit, whether it be paid on a tonnage-basis or be commuted in the form of a lump sum for the license to its use.

However, in view of the immense tonnage of ore smelted annually for the extraction of silver and lead, it is evident that the invention of lime-roasting by Huntington and Heberlein

was an improvement of the first order in the metallurgy of lead.

In the case of non-argentiferous galena, containing 65 per cent. of lead (as in southeastern Missouri), comparison may be made with the slag-roasting and blast-furnace smelting of the ore. Here, no saving in cost of roasting may be reckoned, and no gain in the speed of the blast-furnaces is to be anticipated. The only savings will be in the increase in the extraction of lead from 92 to 98 per cent., and the elimination of matte-roasting, which may be reckoned as amounting to 50c. per ton of ore. The extent of the advantage over the older method is so clearly apparent that it need not be computed any further. In comparison with the Scotch-hearth bag-house method of smelting, however, the advantage, if any, is not so certain. That method already saves 98 per cent. of the lead, and, on the whole, is probably as cheap in operation as the Huntington-Heberlein could be under the same conditions. The Huntington-Heberlein method has replaced the old roast-reaction method at Tarnowitz, Silesia, but the American Scotch-hearth method, as practiced near St. Louis, is likely to survive.

A more serious competitor, however, will be the Savelsberg process, which appears to do all that the Huntington-Heberlein process does, without the preliminary roasting. Indeed, if the latter be omitted (together with its estimated expense of 63c. per ton of charge, or 79c. per ton of ore), all that has been said in this paper as to the Huntington-Heberlein process may be construed as applying to the Savelsberg. The charge is prepared in the same way, the method of operating the converters is the same, and the results of the reactions in the converters are the same. The litigation which is pending between the two interests, Messrs. Huntington & Heberlein claiming that Savelsberg infringes their patent, will be, however, a deterrent to the extension of the Savelsberg process until that matter be settled.

The Carmichael-Bradford process may be dismissed with a few words. It is similar to the Savelsberg, except that gypsum is used instead of limestone. It is somewhat more expensive, because the gypsum has to be ground and calcined. The process works efficiently at Broken Hill, but it can hardly be of

general application, because gypsum is likely to be too expensive, except in a few favored localities. The ability to utilize the converter-gases for the manufacture of sulphuric acid will cut no great figure, save in exceptional cases, as at Broken Hill; and, anyway, the gases of the other processes can be utilized for the same purpose, which is, in fact, being done in connection with the Huntington-Heberlein process in Silesia.

The cost of desulphurizing a ton of galena-concentrate by the Carmichael-Bradford process is estimated by the company controlling the patents as follows, labor being reckoned at $1.80 per 8 hr., gypsum at $2.40 per 2,240 lb., and coal at $8.40 per 2,240 lb.:—

0.25 ton of gypsum,	$0.60
Dehydrating and granulating gypsum,	0.48
Drying mixture of ore and gypsum,	0.12
Converting,	0.24
Spalling sintered material,	0.12
0.01 ton coal,	0.08
Total,	$1.64

The value of the lime in the sintered product is credited at 12c., making the net cost $1.52 per 2,240 lb. of ore.

The low cost allowed for converting may be explained by the more rapid action that seems to be attained with the ores of Broken Hill than with some ores that are treated in North America, but the low figure estimated for spalling the sintered material appears to be highly doubtful.

The theory of the lime-roasting processes is not yet well established. It is recognized that the explanation offered by Huntington and Heberlein in their original patent specification is erroneous. There is no good evidence in the process, or any other, of the formation of the higher oxide of lime, which they suggest.

At the present time there are two views. In one, formulated most explicitly by Professor Borchers, there is formed in this process a calcium plumbate, which is an active oxidizing agent. A formation of this substance was also described by Carmichael in his original patent; but he considered it to be the final product, not the active oxidizing agent.

In the other view, the lime, or limestone, serves merely as a diluent of the charge, enabling the air to obtain access to the

particles of galena, without liquefaction of the latter. The oxidation of the lead sulphide is therefore effected chiefly by the air, and the process is analogous to what takes place in the Bessemer converter or in the Germot process of smelting, or perhaps more closely to what might happen in an ordinary roasting-furnace, provided with a porous hearth, through which the air-supply would be introduced. Roasting-furnaces of that design have been proposed, and, in fact, such a construction is now being tested for blende-roasting in Kansas.

Up to the present time, the evidence is surely too incomplete to enable a definite conclusion to be reached. Some facts, however, may be stated.

There is already reaction to a certain extent between lead sulphide and lead sulphate, as in the reverberatory smelting-furnace, because prills of metallic lead are to be observed in the lime-roasted charge.

There is a formation of sulphuric acid in the lime-roasting, upon the oxidizing effect of which Savelsberg lays considerable stress, because its action is to be observed on the iron-work in which it condenses.

Calcium sulphate, which is present in all of the processes, being specifically added in the Carmichael-Bradford, evidently plays an important chemical part, because not only is the sulphur trioxide expelled from the artificial gypsum, but also it is to a considerable extent expelled from the natural gypsum, which is added in the Carmichael-Bradford process; in other words, more sulphur is given off by the charge than is contained by the metallic sulphides alone.

Further evidence that lime does, indeed, play a chemical part in the reaction is presented by the phenomena of lime-roasting in clay dishes in the assay-muffle, wherein the air is certainly not blown through the charge, which is simply exposed to superficial oxidation, as in ordinary roasting.

The desulphurized charge dropped from the pot is certainly at much below the temperature of fusion, even in the interior, but we have no evidence of the precise temperature conditions during the process itself.

Pyrite and even zinc-blende in the ore are completely oxidized. This, at least, indicates intense atmospheric action.

The papers by Borchers,[4] Doeltz,[5] Guillemain[6] and Hutchings[7] may profitably be studied in connection with the reactions involved in lime-roasting. The conclusion will be, however, that their precise nature has not yet been determined. In view of the great interest that has been awakened by this new departure in the metallurgy of lead, it is to be expected that much experimental work will be devoted to it, which will throw light upon its principles, and, possibly, develop it from a mere process of desulphurization into one which will yield a final product in a single operation.

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[4] *Metallurgie*, 1905, II, No. 1, 1–6; *Engineering and Mining Journal*, Sept. 2, 1905, 398.

[5] *Metallurgie*, 1905, II, No. 19, 460–463; *Engineering and Mining Journal*, Jan. 27, 1906, 726.

[6] *Metallurgie*, 1905, II, No. 18, 433–443; *Engineering and Mining Journal*, March 10, 1006, 470.

[7] *Engineering and Mining Journal*, Oct. 21, 1905, 726.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Biographical Notice of Alexander B. Coxe.

BY R. W. RAYMOND, NEW YORK, N. Y.

(Bethlehem Meeting, February, 1906.)

ALEXANDER BRINTON COXE was born in Philadelphia, Pa., Jan. 19, 1838, the second of five sons of Hon. Charles Sidney Coxe and Ann Maria Brinton. A more extended history of his family and its important relations to the development of the United States will be found in my Biographical Notice of his younger brother, Eckley B. Coxe, published in 1895.[1] It is therefore sufficient to say here that Dr. Daniel Coxe, a distinguished physician and surgeon of London, and a medical attendant of Charles II. and Queen Anne, purchased, in 1684 and 1686, lands in East and West Jersey from grantees of the Duke of York, and became Governor of West Jersey, in which capacity he did much to develop the provincial fisheries, the manufacture of marine salt and pottery, the exportation of timber and the West India trade. In 1698, having acquired the royal patent of the Province of "Carolana," covering (with some reservations) the territory extending from the Atlantic to the Pacific, between the 31st and 36th parallels of N. latitude, Gov. Coxe sent an expedition from Charleston, S. C., to the Mississippi. In 1769, seventy years later, his grandchildren surrendered to the Crown their title under this vast and vague patent, receiving in return a grant of 100,000 acres in the Colony of New York.

The line of his descendants, so far as they concern this sketch, is as follows:

1. Col. Daniel Coxe, his son, b. 1673, who came to New Jersey in 1700; resided there until his death (1730); held many high offices; and issued in London (1722) *A Description of the Provinces of Carolana*, containing probably the earliest published plan of political union for the British Colonies in North America.

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[1] *Trans.*, xxv., 446.

2. His son, William Coxe, b. 1723, d. 1801, an enterprising colonial merchant and trader.

3. His son, Tench Coxe, a leading political economist and statesman of the period immediately following the American Revolution; delegate to the Continental Congress; Hamilton's Assistant Secretary of the Treasury; the introducer of the Arkwright loom; the earliest and most influential advocate of the production of cotton in the United States; the prophet of the use and value of coal as fuel; and the purchaser, in reliance upon his own prophecy, of large tracts of coal-land in Pennsylvania.

4. His son, Charles Sidney Coxe, b. 1791, d. 1879, a distinguished lawyer, at different times District Attorney, and District Judge in Philadelphia, who devoted himself, outside of his professional duties, to the preservation and administration of the coal-lands of his father's estate, and who educated his sons with special reference to the future conduct of the great development foreseen by him.

Alexander, the second of these sons, is the subject of the present sketch.[2]

Alexander Brinton Coxe was educated first at the classical school of Dr. Faries, recognized for more than fifty years as the best of its class in Philadelphia. A good student, like all his brothers, he was able, at the age of fourteen (1852) to enter the University of Pennsylvania, where he was graduated in 1856. Fond of open-air exercises, and especially of rowing, he pulled an excellent oar in the University Barge Club. After graduation, and with a view to the future duties of his life, he spent two or three years in a Philadelphia counting-house of the old school, where the traditional methods of commerce and trade were rigidly observed and taught. Of course, these old fashions were already giving way to newer ones, under the pressure of altered conditions; and Mr. Coxe, conducting in after years a business of production, transportation and trade, the extent, complexity, and intense activity of which would have paralyzed the energies and systems of his first employers, may have smiled

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[2] For many of the particulars of this sketch, I am indebted to Mr. John Cadwalader, of Philadelphia, a brother-in-law of Eckley B. Coxe. Indeed, I might have copied *verbatim* the excellent account sent me by Mr. Cadwalader, but for my desire to interpolate personal knowledge and comments of my own.

as he recalled their maxims and methods. Yet, in business as in politics, a thorough knowledge of the old is the only safe basis for an intelligent judgment and choice of the new. At all events, the subsequent honorable career of the firm of Coxe Brothers & Co. exhibited, through all modern novelties of organization and operation, the old-fashioned virtues which no amount of progress can afford to discard.

As a further preparation for his life-work, Mr. Coxe made, at the age of about twenty-two, an extended tour in Europe, returning from which, soon after the beginning of the War of the Rebellion, he entered the Union army as an Aide upon the staff of Major-General Meade, who highly esteemed his character and service.

In 1865, the firm of Coxe Brothers & Co. was formed for the development of the anthracite-lands inherited from their grandfather, Tench Coxe, and preserved, with prescient labor and sacrifice, by their father. For forty years (until, a few weeks before his death, the property of the firm was transferred to the Lehigh Valley Railroad interest), Alexander Coxe devoted himself unremittingly to that great business. Three of his brothers and a cousin (Franklin Coxe), who had constituted the original firm, successively died, leaving him, at last, to carry alone the burden of this immense responsibility. His brother Eckley, who died in 1895, had always been, not only the technical manager of the colleries operated by the firm, but also the most evident and eminent representative of its position and policy. Fortunately, he had lived long enough to settle many questions involved in his own peculiar department of administration, so that, for the succeeding ten years, the skillful engineers of the house were doubtless able to take his place. But during his life-time, no less than after his death, the all-important financial management and undertakings of Coxe Brothers & Co. were chiefly directed by his brother Alexander. And I had occasion to know personally that the two brothers consulted freely, and acted in perfect harmony, upon all subjects connected with any part of their business.

One of the most important of these subjects was the relation of the firm to its working employees. In my Biographical Notice of Eckley B. Coxe, already cited, I have described and discussed at some length the principles and the policy of the house

in this respect; and that statement need not be repeated here. But I then realized that, even in eulogy of the departed, I ought not to ignore the merits of the living; and I am now glad to find that I expressed that feeling in the following foot-note,[3] which I regard as worthy of repetition:

"It is impossible to separate, in such matters, the part taken by the family as individuals from that of the company which was their business representative, or the part of Eckley B. Coxe himself from that of the kindred who so heartily united with him in every good work. While I comply with their own desire, as well as with the general rule of justice, in ascribing to him the credit for the undertakings of all kinds in which he was, so to speak, the official leader, I cannot forbear to say here, once for all, that I do not believe he could have accomplished, and I scarcely believe he would have undertaken, so much, without the cordial and effective support of his wife and his brothers and sisters. This qualification does not in the least detract from his fame; and, on the other hand, it furnishes the assurance that his wisely benevolent schemes and policies will not end with his death."

The expectation thus expressed has been fully realized in the years which have since elapsed.

Soon after entering upon active business, Mr. Coxe married Sophy, daughter of Richard Norris, of Philadelphia, who, with a married daughter (Mrs. Charlton Yarnall) and four grandchildren, survives him. But no account of his life would be complete without mention of his son, Daniel, who bore the name, and inherited the ability, of distinguished ancestors, and in whom a father's affection and ambition was centered. Unfortunately, this only and gifted son was handicapped in youth by physical frailness, which required unremitting care, change of climate, etc. As he grew older, he became stronger, and was able to exercise effectively his exceptional taste and talent for mechanical engineering. He designed and constructed a locomotive which was highly approved by expert railroad-engineers; and he constructed a narrow-gauge track, upon which practical tests of his invention could be made. His models were exhibited at the Chicago Columbian Exhibition in 1893. It was a doubly cruel blow to his proud and loving father, when this promising son, after surmounting the perils and drawbacks of physical weakness, was killed by the accidental upsetting of his own engine upon his own track. Concerning such a bereavement, I can say nothing, because I know so much. But

[3] *Trans.*, xxv., 467.

I may be permitted to bear witness to the encouragement and help derived from the example of a father, thus stricken and stripped, who still recognized the claims of duty, and, with courage and patience, " endured to the end."

Alexander B. Coxe was by no means limited in his sympathies and activities to the sphere of his own business. He occupied many positions of trust, among which may be named those of director of the Lehigh Valley R. R. Co., the Pennsylvania Co. for Insurance, etc., and the old Mutual Assurance Co. (familiarly known as "The Green Tree"), the duties of which he faithfully discharged. In social matters also he was an influential participant, securing by kindliness and courtesy the good-will of all.

Until within a very few days of his death, he appeared to be in excellent health, though he had undoubtedly overstrained his energies in recent labors, and had thus lost the power of resistance to a sudden attack of disease. So it came to pass that he succumbed to a severe cold, developing into pneumonia —the malady so fatal to patients advanced in years, and the one which, according to high authority, still remains beyond the comprehension or control of modern medical science—and, after a brief illness, died Jan. 22, 1906, leaving behind him a multitude of mourning friends, and the memory of a long, blameless, fruitful life.

Mr. Coxe joined the Institute in 1880, and, although fully qualified to be a Member, modestly preferred to receive, and to retain for twenty-five years, the title of Associate.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Internal Stresses and Strains in Iron and Steel.

BY HENRY D. HIBBARD, PLAINFIELD, N. J.

(London Meeting, July, 1906.)

I. *Introduction.*

A NOTED ordnance engineer once said to a friend, in speaking of the production of great steel guns, "How is it? We design our guns with a factor of safety of eight, and the guns burst."

The vague way in which internal stresses and strains in iron and steel are often considered and spoken of makes it worth while to examine them, as to their nature, their causes and results, how they may, for useful purposes, be advantageously dealt with, and how, when detrimental or dangerous, they may be reduced or kept within harmless proportions.

Rankine defines "strain" as a change of form or dimensions of a solid or liquid mass produced by a stress. This definition seems not intended to cover strains due to internal stresses, and it will help us in the present inquiry to consider strain as a tendency to change as well as an actual change of form.

Internal strains in iron and steel are the result of stresses within the mass of the piece, some parts pulling and others pushing in resistance to them; or, in other words, some parts are in tension and some in compression, each part striving to relieve itself from strain and make the piece assume a form in which all parts are at rest. Subdivision, so that each part could relieve its strain by motion relative to the other parts, would, if carried out far enough, practically obliterate strain.

The internal strains we are now to consider are not those due to the stresses of the service which the piece is rendering, either alone or as a part of a structure, which may be termed service-strains, but those which originate or at least are contained in the piece itself.

Internal stresses in a piece of metal are, like action and reaction, always equal and in opposite directions. The stresses

of every part in tension are balanced by those of other parts in compression. If a part chiefly under tension is removed, as by cutting it away from the piece, the remainder will at once adjust itself so that the stresses are equalized, and a part which has been under compression will become under tension, while the total amount of stress in the piece will be reduced, accompanied by a change of shape, because the remainder of the piece will not have then the same amount of compression- and tension-stresses. Cutting metal away along the neutral axis of a bar, however, as, for instance, by drilling a hole through the center of a flat cold-rolled bar, often may be done without causing an appreciable change of shape.

The importance of internal strains depends on their intensity as well as on the ductility of the metal. Strains which could be allowed with impunity in a ductile or tough steel might be fatal to the integrity of the piece were the metal a hard, brittle variety.

Strains exist in all pieces of cold iron and steel, but as the term is generally used it refers only to such as are made apparent in some way, such as causing a change in the physical properties, rupture, danger of rupture or change of shape of the piece.

Internal strains reduce the specific gravity of a piece of iron or steel. Consequently, the metal is heaviest when it is in the annealed state, meaning that variety of annealing which is the result of heating to redness followed by slow cooling. It is a common error to assume that a piece of steel which has been cold-hammered or cold-rolled or wire-drawn is "more dense" after these operations than it was before, when it is actually lighter.

Internal strains accompany if they do not indeed cause inferior resistance of the metal to chemical action. A file broken off, and the broken end immersed in dilute hydrochloric acid, has been found to have lost a greater thickness of metal from the hardest part, at and near the outside, in which the strains are greatest, than from the less hard central portion. The quick corrosion of wire-nails and wire-fence may possibly be ascribed to the cold-worked condition, and directly or indirectly to the internal strains. The corroding agent more readily enters the mass of the metal, it may be, because of larger intermolecular spaces.

For the purpose of this paper, internal strains in iron and steel may be divided into two classes, according to the causes which produce them, viz.:—

1. Those caused by an irregular rate of change in temperature, that is, of heating or cooling.

2. Those caused by cold-working or permanent change of shape of the piece under consideration by mechanical means at atmospheric temperatures, or at least at temperatures below that at which the metal is softened.

II. *Internal Strains Caused by an Irregular Rate of Change of Temperature.*

This class of internal strains is by far the more important of the two.

Because iron expands when heated and contracts when cooled, and indirectly for other reasons, hereinafter noted, internal stresses and therefore strains, varying in all degrees from harmless to fatal, exist in all pieces of iron and steel. This arises from the fact that all commercial iron and steel is the product of processes involving heat, the strains in most cases being those set up by the more or less irregular rate of cooling.

The rate of change of temperature may act in a purely physical manner in producing strains, as will be considered later; or, when it comprises quenching a piece of steel from a high temperature, when it may have also a chemical effect on the metal which, by changing the properties thereof, reducing ductility and increasing elastic limit until that perhaps coincides with the ultimate strength, exercises a potent effect on the resulting strains.

The amount of change in temperature does not affect the strains produced. The rate determines all.

The strains due to irregular cooling, unless chemical changes are involved, are apparently between part and part. Those due to cold-working may be considered as between molecule and molecule because of the disarrangement of the molecular formation. The latter results usually in strains between the parts as well.

Strains which come under this division of the subject should be considered under two aspects. (1) Those which arise during the continuance of the causes which produce them,—that

is, temporary strains, and (2) those which remain after their causes have ceased to act,—that is, permanent strains. Temporary strains in many cases become permanent, especially when set up during cooling at an irregular rate. The phenomena of permanent strains are, during their formation, the same as of temporary strains.

The following cases will illustrate the two ways in which each kind of strain may result in rupture of the piece. When an ingot of hard steel is placed in a red-hot furnace, and is so ruptured internally by the faster expansion of the exterior, due to the rapid heating it undergoes, that it separates into pieces when forged or rolled, its ruin was caused by strains occurring while the cause, namely, the quick heating, was in operation. This is a typical example of temporary strains in steel. When a boiler-plate of soft steel, lying cold on the floor of the shop, cracks suddenly, it is because of strains existing after their cause had ceased its action. This is the usual kind of internal strains occurring in iron and steel, and is the kind chiefly meant in what follows in this part; it is an example of permanent strain. These two instances cited are, it will be understood, extreme cases, in which the piece is ruptured by the intensity of the strains.

Strictly speaking, permanent strains are but relatively permanent, since they decrease when the piece is again heated, or through the seasoning or annealing action of time. When strains result in rupture of the piece of metal, they are thereby much reduced in amount and otherwise modified.

While strains are unavoidable, they are—except in special cases—undesirable in proportion as they are great. The exceptions arise when the strains increase desirable properties, as, for instance, hardness in hardened steel.

Expansion and contraction of iron and steel by change of temperature does not, if the new temperature has become uniform throughout the piece or structure, set up new permanent strains or materially change those existing between the different parts of the piece or structure, provided that the different parts are all of the same kind of metal, or at least of metals having the same coëfficients of expansion. In a structure made of metals having different coëfficients of expansion rigidly fast-

ened together, a change in temperature is sure to change the strains, increasing or decreasing them.

The intensity of the strains considered in this part depends on the following determining factors:—

1. The rate of change of temperature;
2. The shape of the piece;
3. The bulk or volume of the piece;
4. The elastic limit of the metal;
5. The ductility of the metal;
6. The coëfficient of expansion of the metal.

1. The rate of change of temperature is the great governing condition producing or reducing internal strains both temporary and permanent. The faster the rate, the greater the strains. The amount of change, however great, is unimportant in this connection if the rate be sufficiently slow.

The rate depends on the difference between the temperature of the piece of metal and that of its environment, and on the heat-conductivity of the metal. The greater the difference in the temperatures mentioned, the greater the strains resulting, and the greater the heat-conductivity, the less the strains. A poor heat-conductor, like manganese steel, must, if of massive form, be heated very slowly if dangerous strains are to be avoided.

Extreme cases in which the rates of change of temperature are the greatest met with in the practical manipulation of iron and steel are: for rising temperature, when the article is placed cold within the hot heating-chamber of a furnace, and for lowering temperature, when it is taken heated from a furnace and plunged into a cooling bath.

With the exceptions noted later, any change in temperature up or down below the degree of heat at which it softens, produces in a piece of iron a somewhat irregular rate of heating or cooling, and hence strains; because, as heat must enter and leave the article through its exterior surface, the portions of the article adjacent to the heated or cooled surface will be warmer or cooler than the parts farther away from such surface. Time is required for heat to pass from one part of the article to another, due to imperfect conductivity of the metal. It follows, therefore, that during a change of temperature strains are set

up within the piece, through the differences in expansion and contraction, due to differences of temperature of the parts. These differences vary in degree with the rate of change in temperature, being the greater for a given iron or steel article the more rapid such rate of change.

To avoid danger to the piece from this cause, which is the one to which may be directly laid nearly all the actual damage done by strains in iron and steel, one must maintain less difference between the temperature of the article and that of its environment. If the dangerous strains arise in heating the article, it must be heated more slowly. The heating-chamber or receptacle must not be too much hotter than the article placed therein. In extreme cases, the chamber and the article must be slowly heated together, this procedure being called for, however, only in the heating of bulky articles of very hard iron or steel.

When dangerous strains are liable to arise from too rapid cooling, they may sometimes—as in the case of a cast-iron car-wheel—be relieved or reduced in intensity by a slower rate of cooling, the red-hot wheels being piled up in tight soaking-pits built in the ground, and allowed to cool very slowly, consuming several days in the operation. The lowering of the temperature of both the thick and thin parts is maintained at a rate sufficiently uniform to ensure their reaching ordinary atmospheric temperatures at about the same time; the thicker parts do not then continue their contraction after the thinner have ceased theirs, which action, if it took place, would result in strains that might easily be dangerous to the integrity of the wheel, in view of the almost total lack of ductility in the cast-iron of which it is made.

Many steel castings may not be allowed to cool in the open, or even in the sand, without danger of spontaneous rupture from internal strains, but must be placed while still hot in a heated receptacle, usually a furnace, and allowed to cool with the furnace at a much slower rate than if in the open air. Steel wheels, as well as the iron carwheels mentioned above, usually require such treatment, though the ductility of the softer grades may admit of its omission. On the other hand, the greater coëfficient of expansion of steel tends to set up greater strains than those of the iron wheels.

When, however, the rate of cooling may not be reduced—as in quenching, in the heat-treatment of steel, where it must be rapid to give the metal the properties desired—strains may be kept within the danger-point only by having recourse to the modifying conditions which are noted later, and chiefly those relating to the shape and bulk of the piece and methods of heating and cooling.

In special cases, for example, in cutting-tools of steel where only the cutting-edges demand the rapid change of temperature, some relief, often adequate, is to be afforded by heating only the cutting-edges themselves to the hardening heat. Then the remainder of the article will not have to undergo such a rapid change of temperature as if made as hot as the hottest part, and the resulting strains in the tool will be much lessened and perhaps made harmless.

If a piece of cold iron or steel of uniform temperature, in which the strains are the result of cooling, be cooled further, uniformly as to the exterior surface, the strains will be temporarily reduced and may be wholly eliminated during the cooling operation, only to be restored much as before when the temperature of the piece has again become uniform. Such a piece of steel presents during the further cooling the only exception to the statement that all pieces of cold iron and steel have internal strains. A further practical exception is found in the case of a piece of cold iron or steel which has been cooled from a red heat, at which it is too soft to have strains, at an exceedingly slow rate, as in the case of the carwheel mentioned. When the slow rate of cooling is actually continued to atmospheric temperature the article is practically free from strain.

When a piece of iron or steel containing intense strains is heated in one part gently—it may be to 200 or 300° F.—the strains are changed so that when the piece is cold it is not exactly of the same shape as before. It may not be possible to determine this fact by measurement, but it may be made apparent by the fit of two such pieces together before and after one of them has had its strains changed by the partial heating.

Spontaneous cracks in cold soft steel are still not wholly explained. When such cracks occur in hard and hardened steels or in cast-irons which have practically no ductility, they are easier to understand, though even in such cases just what was

the "last straw" which caused the rupture is not usually apparent. This is on the assumption that the composition of the steel is suitable, particularly as regards phosphorus and oxygen, which must not be present in too great proportions, and further, that the steel was well cast and rolled or forged.

Whether or not in the case of the soft steel boiler-plate it was an additional strain due to a slight change in temperature, or vibration from some outside cause, or that the fatigue of the metal under strain progressed more rapidly than the relief of strain due to time, and the operation of what might be called annealing by natural causes, is not clear. It is probably directly due to the last of these possible causes following a lessening of the ductility of the metal through working of the piece at the well-known critical temperature termed the "blue-heat." Spontaneous rupture never occurs in an old article of iron or steel, provided, of course, that no new strains have been set up within it.

2. The shape of the piece of metal affects strains very greatly when it is heated or cooled. If it be made up of relatively thick and thin parts continuously connected to each other, such as the thin web and thick hub and rim of a car-wheel, on changing its temperature strains will be set up within it, not only between the interior and surface portions but between the thick and thin parts as a whole. In the case cited of a cast carwheel, these latter strains are those which are dangerous, causing the breakage and consequent destruction of the usefulness of the wheel if they be allowed to develop to their fullest extent by allowing the wheel to follow its own rate of cooling in the open. So, for a given change in temperature, the shape of the piece is very important in determining the degree of strains it possesses.

The reason for strains due to shape is that, when heated in a hotter environment or cooled in the open or in a cooler medium, the thinner parts reach the surrounding temperature sooner than the thicker parts, and consequently do their expanding or contracting so much the sooner, and strains result from the slower and later expansion or contraction of the thicker parts.

Large plane surfaces tend to intensify strains due to change of temperature of a piece of iron or steel either from heating,

cooling from a high or casting temperature, or quenching. The reason is obvious. The plane surface, cooling or heating more quickly at its edges than elsewhere, cannot yield to internal tension- or compression-stresses by change of shape, as such stresses act in straight lines within the piece. Relief may sometimes be afforded by curving or corrugating the surface, as in a casting; but a flat sheet like a saw-blade may not admit of this, and then means must be employed to conduct the operation of hardening the teeth, when the strains are set up, so that they will not crack the saw. In the case of a large circular saw-blade, partial heating, as described above, is used, and is effected by protecting the central portion of the sheet with thicker iron plates during the heating and cooling operations. The protected portion is not hardened, and has therefore a lower elastic limit and higher ductility than the hardened rim, and will thus yield a little without breaking.

3. The bulk of the piece of metal has great influence on its strains when its temperature is changed because of the distance which heat must be conducted between the surface and interior parts. When the bulk and therefore this distance is relatively great, the strains are great in proportion, and when the bulk is small they are less.

High conductivity of heat tends to offset great bulk in the strains resulting from a change in temperature.

With a piece of metal of a given contour the strains from either cause may be much reduced by reducing the bulk by means of recesses or slots or other holes properly made in the piece. The quenching operation in particular then causes much less strain.

In the case of a large tap this principle is applied by drilling a hole along its axis, which has a double effect. First, it allows the cooling fluid to cool the interior nearly as quickly as the exterior as a whole, and secondly, it reduces the actual thickness of the metal to a fraction, perhaps a third, of what it would be otherwise, and in that way reduces the strains due to bulk.

There are many ways in which the use of holes and recesses within the contour of the article may so reduce the bulk that without detriment to its use the thickness may be brought within safe limits to admit of it being cooled from a high heat

in a cooling bath without being in danger of cracking from the internal strains set up.

Solid steel armor-plates are sometimes cracked internally by the cooling strains arising from the quenching operation, though the steel is rather soft, with carbon from 0.20 to 0.25 per cent., except the hard face.

This may be due to either or both of two causes. (1) When the mass of the armor-plate or other piece of iron or steel is so great that the final contraction of the interior portions when cooled may not be compensated for by a reduction of cross-section of the metal (such as occurs when a test-piece of ductile metal is pulled apart in the testing-machine), then internal cracks may occur from the metal being over-strained, regardless of the ductility of the metal. (2.) The ductility of the soft steel of the body of the plate is impaired by the long-continued heating without work during the carbonization by the cementation-process of the face, which is to be hard, and for that reason will not endure internal strains as well as its composition would indicate. Holes or recesses not being admissible, though they have been recommended by some, reforging or annealing to break up the coarse crystalline structure existing in the plate is resorted to, after cementation, in an effort to avoid this defect. Nevertheless, the results are not always as desired.

It does seem, however, that careful experiment should develop a method for making a large soft steel ingot, with a high carbon steel layer on one side, which could be forged into an armor-plate, thus avoiding the expensive and harmful cementation process.

When an article of iron or steel is liable to crack in service from strains, the danger is sometimes best avoided by making it in two or more pieces. This practically amounts to putting cracks in the thing, but often they may be located so as to cause no trouble. The following example will illustrate: A cast-iron bottom-plate, on the center of which was cast a large ingot of steel, was broken the first time used, by the expansion of the central part heated by the molten steel. On making a plate for the purpose, of four pieces bolted together, no further trouble from this cause resulted.

4. The elastic limit of the metal affects the intensity of the

strains, because when it is low it may allow the metal to yield under the stresses which cause strains so as to relieve them in part.

5. Ductility of iron or steel sometimes allows it to yield without fracture under stresses of sufficient magnitude, so that the strains are in some degree lessened. A highly ductile metal rarely or never breaks from internal strains unless extremely massive.

A metal supposed to have great ductility may actually have very little, due perhaps to ill-treatment. The boiler-plate mentioned had probably been damaged by working at the black or blue heat, so that its ductility was impaired, and the strains arising from irregular heating and cooling were more than the remaining ductility could allow for, and rupture ensued. The armor-plates cited also had their ductility much reduced by the long heating during cementation.

When, as in cast-iron and hardened high-carbon steel, there is no ductility, and the elastic limit coincides with the ultimate strength, the strains set up in cooling cannot be relieved, and may easily reach an intensity which will cause the piece to crack or break.

6. The coëfficient of expansion, strictly speaking, wholly determines the intensity of the strains arising from irregular rates of change of temperature in metals, for if it became zero such strains would not occur. The greater the rate of expansion the more intense become the strains arising from a given rate of change in temperature.

Heating a piece of iron or steel to any degree below the temperature at which it softens, will increase the strains within it in proportion to the rate of heating. Therefore, heating to relieve dangerous strain, which is often resorted to, must be very slowly done, so that the interior is heated nearly as fast as the exterior, or the extra strain due to the more rapid expansion of the exterior parts may cause the rupture it is the purpose of the heating to avoid.

By such slow heating something like the seasoning effect of time and slightly higher than atmospheric temperature is given to the piece. This effect may be used on large massive heat-treated articles of high-carbon steel, such as heavy cutters and projectiles and heavy articles of toughened manganese steel,

all of which are in a high state of strain, due to immersion at high temperature in a cooling bath.

The increase of strain due to even slow and moderate heating, as, for instance, to the temperature of boiling-water, may be used for testing hard heat-treated objects, such as armor-piercing projectiles, to determine whether or not they are in a dangerous condition, or rather to separate those in danger of spontaneous rupture from those which are not. Without some means for discriminating between them, some of them may lose their points by spontaneous rupture months after they are made and have travelled far.

If the article is, because of internal strain, close to or at the danger-point, the extra strain will cause it to crack or break, while, if it does not break from such heating, it will have when again cold a margin of safety represented by the additional strain caused by the gentle heating. Moreover, it has had its strains somewhat reduced thereby, and is therefore not likely afterward to break spontaneously.

When a cold massive piece of steel, as an ingot, is to be heated in a furnace, it is a matter of importance to know whether its previous cooling was rapid or slow. If rapid, it may contain so much strain as to be ruptured internally by the heating operation, while if it has been slowly cooled it may, because of smaller internal strains, endure that operation safely. To reduce strains in ingots which are to be cooled to the atmospheric temperature, the rate of cooling should be retarded.

III. *Internal Strains Caused by Cold-Working.*

The strains due to cold-working iron or steel are the result of molecular displacement and very likely of mere changes in the inter-molecular spaces, but the theory of the matter we may for the present leave out of consideration.

The phenomena occurring with these strains include higher tensile strength, higher elastic limit, greater hardness, less ductility and lower specific gravity. Perhaps it is not claiming too much to say that these modified properties are the direct result of the strains, as, if the strains be destroyed by heating to redness, all these modifications disappear with them and the properties of the metal are substantially those it possessed be-

fore the cold-working operation was performed upon it. For the purposes of this paper, therefore, these modified properties may be considered as the result of the strains.

Strains are an unavoidable accompaniment of cold-working iron and steel. Those due to cold-rolling or wire-drawing purposely applied have often useful effects when properly taken advantage of, while harmful or undesirable effects may be avoided by reducing them by annealing or other proper heat-treatment. When the pieces of metal so cold-worked are not large and the ductility considerable there is no danger of spontaneous rupture. The cold-working may, indeed, be continued so as to cause dangerous strains if they be not relieved by heating. The service of larger pieces may be such that they are subjected to cold-working, as in the case of a die ring for a centrifugal ore-grinding machine, which will cause flow of the metal with resulting strains, and may distort the piece or even tear it apart or break it.

Something like spontaneous rupture is met with in cold-rolled or cold-drawn shafting when the cold-working of the surface portions has so extended them that the interior is strained beyond its strength and thereby ruptured at intervals across the shaft. In that case, when the outer portions are turned off the bar may drop apart.

The beneficial effects of strains due to cold-working come from the higher tensile strength and elastic limit of the metal.

Drawn or cold-rolled shafting is much stronger per unit of cross-section than before the cold-working, and wire may be made whose ultimate strength is increased several times by the strains set up in the drawing operation. Wire-drawing strains give to some varieties of spring wire the greater part of their springiness.

The increased strength of iron and steel wire due to the strains of cold-working is made useful in many ways. In the wire cables of suspension-bridges it is relied upon and figured in as part of the tensile strength of the wire.

In wire for piano strings and for deep sea-sounding, tensile strengths of over 400,000 lb. per sq. in. have been attained, the greater part of which is due to the internal strains set up in the wire-drawing process.

The effect of seasoning or annealing by time on cold-worked

iron or steel, such as wire, is probably not known, but is very likely an appreciable amount, which, in the case of bridge-wire, for example, may reach important proportions with the lapse of decades.

Strains in cold-worked iron or steel may be detrimental in a way. A piece of straight cold-drawn shafting if machined, as, for instance, in key-seating or in turning, is very liable to be not straight after the machining, as cutting away a part of the strained metal removes part of the stresses, and those remaining cause the resultant effect to be different from what it was, and the new adjustment necessary is found in a new shape of the piece. In other words, the shaft will not be straight.

The modifications and removal of strains due to cold-working by heating for long or short periods of time, one or more times, to temperatures below redness requires investigation. By these temperatures is meant those all the way down to atmospheric, and especially those from 212° to 408° F., the latter being the temperature at which a faint straw color is given to steel of a certain composition. Removal of dangerous strains by subjection to heat not great enough to discolor the surface of the metal would be a good thing in many ways, if feasible. A cold-worked piece of shafting, which will break off in the lathe when the outer skin is removed, might perhaps be practically cured by such heating between the rolling- or drawing-operations.

In the specifications for wire for a great suspension-bridge, the wire as drawn must have a tensile strength of 215,000 lb. per sq. in., and after galvanizing must have a tensile strength of 200,000 lb. per sq. in. This decrease of 15,000 lb. per sq. in. is the loss of strength due to removal of strains by heating the wire for a brief period to the galvanizing temperature, or, say, to 800° F. If the heating even at that temperature were long continued, a much larger loss of tensile strength would no doubt result.

IV. *Conclusion.*

The seasoning effect on iron and steel by time, referred to in the foregoing, while generally admitted to exist, is but little known, and scarcely anything has been recorded, if indeed done, toward the elucidation and enunciation of the laws which govern it.

It is held to be a fact that old iron and steel articles, years old, never have excessive strain and never fail through spontaneous rupture. It may, of course, be argued that they do not fail that way when old because if they contained enough strain to break spontaneously, they would have so broken when comparatively new; or, further, that if dangerously strained the fatigue of the metal would, in comparatively short time, allow it to break without any diminution of the strain. These arguments may be reasonable, but many believe, nevertheless, that there is a reduction of strain in iron and steel by the seasoning effect of time.

Old cast-iron cannon which had given the normal amount of service were said to have had their strength restored by years of rest. The strains in such cannon were, it is true, the result of service-stresses, but such strains in this case are analogous to those produced by cold-working, and especially as far as they are affected by annealing by time. In the case of an article of hardened steel, seasoning or annealing by time is held to relieve strains with the result that the piece is freed from danger of spontaneous fracture or change of shape after being finished, while if unhardened its strength and ductility are increased by such seasoning. In cold-worked steel the strength will probably decrease in time, as will the elastic limit, while the ductility will increase.

It is probable that such effect as is produced by time upon a piece of iron or steel is chiefly the result of alternate heating and cooling within the limits of the daily range of temperature, but there is evidence indicating at least that seasoning is effected by time alone, whether or not the temperature of the piece is subject to change.

It is not hard to conceive of the molecular change or rearrangement necessary to the removal of strains at ordinary temperatures if it be admitted that all molecules of matter are in a state of vibration by heat at any temperature above absolute zero or –273° C. The molecules naturally would (it seems evident) shake themselves into more regular formations, which would relieve each one from crowding or being crowded by its neighbors, or that the molecules would, by such formation, allow the parts in tension to lengthen and those in compression to shorten the slight amount needed to relieve the

strains in part, at least, that is, when the intensity of the strains is great. With less intensity the relief of strain from such action would manifestly be lessened, and it is hardly supposable that all strain would be eliminated by seasoning to any finite extent. Either or both of these molecular adjustments would result in diminished tension and compression, and therefore of strain in the piece.

At high temperatures this shaking of molecules into regular formations results, in time, in coarse crystallization, a further step which has results of its own in reducing strength and ductility.

Consideration of this question of seasoning by time brings up the very interesting one previously alluded to, concerning which we are as much or more in the dark, which is that of annealing iron and steel at low temperatures, that is, in the first phase, at not higher than 212° F.; in the second phase between 212° and the lowest temperature at which steel will be given the faintest straw color, about 408°; and in the third at temperatures between this and red heat. The temperatures giving steel the tempering colors, straw, yellow, blue, etc., vary for different grades of steel, and therefore cannot be stated exactly for steels as a whole. There is much to be learned in these fields, and the second of the three mentioned seems especially to hold out hope of practical benefit to mankind from applications of its laws. We need to know the effect on each kind of steel object in every condition of size, shape, composition and treatment, of time, temperature and fluctuations of temperature within the limits named.

The amount of experiment to determine all these points in all degrees will be very large, but in the interest of pure as well as applied science it should be undertaken.

Annealing by time may be expected to act in a different way on cold-worked steel in which the strains may be the result of disturbed molecular arrangements, from that on hardened steel, in which the strains result in great part if indirectly from the chemical constitution of the steel.

Perhaps it can be determined just how much of the hardness of hardened steel is due to chemical change and how much to strain. If there is no chemical change in heating hardened high-carbon steel to temperatures not higher than the blue

color, or even higher, say, to 800° F., then it would appear that any hardening or increase of tensile strength or decrease of ductility which is removed by heating, short or continued, to temperatures not above the blue or the higher degree mentioned, is due to the strains in the piece. The properties due to chemical constitution will then be permanent in the absence of high heat, while those due to strain may fade in time. Internal strains when in moderate degree may either increase or decrease the tensile strength of steel, as shown by many tests of steel in which annealed bars sometimes show higher, but usually lower, tensile strength than the unannealed.

That strains in hardened steel are of a quite different nature from those in cold-worked steel, may be shown by the attraction of a magnet. A piece of hardened steel with and without intense strains acts very differently from a piece of wire-drawn steel with and without strains when its attraction for or by a magnet is measured.

A file in a hardened condition, which gave a pull of 12 oz. with a common horse-shoe magnet, gave, after being heated to the blue heat, a pull of 27 oz., and after being heated red hot and slowly cooled, 31 oz. The magnet gave on its keeper a net pull of 43 oz.

Tenpenny wire nails have with the same magnet an average pull of 27 oz., while similar nails, heated to redness and slowly cooled, an average pull of 24 oz. In the nails the strains seemed to have no effect in reducing the amount of the pull, but, if anything, to increase it. Still, the determination was made by crude means, and cannot be accepted as doing more than indicate the effect of the cold-working on this property. The apparatus consisted of a small spring-balance, the magnet and pieces under examination.

In the case of the file the question is more complex. If the carbon is not changed in chemical condition by heating to the blue heat, as has been maintained, then the great increase in the susceptibility to attraction by a magnet must apparently be laid to the elimination of strains. If not, then to an allotropic modification of the iron itself.

Beyond the scope of this paper is the consideration of the chemical and physical results of rapid change of temperature, as in the hardening operation when they both affect the strains.

There is so much to be done experimentally in that field that in the absence of the experimental data too much must be left to speculation at this time to make it worth while. No solution of the problems presented by the phenomena of the hardening and tempering of steel, however, will be complete which does not deal with the strains arising, their causes, results, and proper treatment.

Neither is the mathematical treatment of the matter of strains here considered, requiring as it does examination of intricate problems involving variations in temperature, coëfficients of expansion, moduli of elasticity in tension and compression and at different temperatures, physical properties, varying kinds and intensity of strain in the different parts of the piece, and perhaps other important factors. Other investigators, better able to cope therewith, may find the matter attractive. This feature of the case must be dealt with, however, or the guns will still burst.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Heat-Treatment of Steels Containing Fifty and Eighty Hundredths Per Cent. of Carbon.

BY C. E. CORSON, LATROBE, PA.*

(London Meeting, July, 1906.)

I. INTRODUCTION.

THE experiments of which the results and significance are set forth in this paper do not by any means cover the whole subject of the heat-treatment of the material referred to, yet they constitute a contribution to that general subject, rather than to the special department of annealing.

The material here considered is acid open-hearth steel, containing from 0.50 to 0.80 per cent. of carbon, with a nearly uniform percentage of other elements. This class of steel is rapidly increasing in commercial importance. It is even rumored that the rail-specifications of some railroads will hereafter require open-hearth steel. Yet this particular grade seems to have received less study and description from the standpoint of the metallographist than many others.

The investigation here described was directed to the following points:—*Steel containing about* 0.50 *per cent. of carbon:* 1. The structure as related to the temperature, at the same rate of cooling; 2. The structure and physical properties as related to temperature at different rates of cooling; 3. The structure and physical properties as related to different finishing-temperatures and different rates of cooling; 4. The bearing of these observations upon the statement of Prof. Albert Sauveur.[1]

* Metallographist of the Railway Steel-Spring Co.

[1] "Hot work, as such, has no influence upon the structure of the metal. Indirectly, however, by retarding crystallization until a lower temperature is reached, it may influence its structure most decidedly; but the same results could be accomplished by heat-treatment alone, i.e., by re-heating the unworked metal to the temperature from which the unworked piece was allowed to cool undisturbedly." *The Metallographist*, vol. ii., p. 267 (under the head of "Changes of Structure Brought About by Work").

Steel containing about 0.75 *per cent. of carbon:* 1. Physical properties, as related to temperature at different rates of cooling; 2. Physical properties, as related to different finishing-temperatures and different rates of cooling; 3. The bearing of these observations upon the statements of Prof. H. M. Howe.[2]

Steel No. 193	C, 0.70	Si, 0.141	Mn, 0.068	P, 0.012 S, 0.019
Slowly Cooled After Heating to Deg. C.	Tensile Strength. Lb. Per Sq. In.	Elastic Limit. Lb. Per Sq. In.	Elong. on 8-In. Per Cent.	Reduction of Area. Per Cent.
750	82,660	40,062	12.00	25.42
1,100	92,342	59,363	13.12	20.35
1,300	48,921	29,247	1.12	17.22
1,400	41,327	33,082	1.25	15.10

Evidently, after passing 1,100°, the maximum had been reached.

The temperatures were determined by a Le Chatelier pyrometer.

The micrographs here given as illustrations are magnified to 60 diameters. The etching-solution was one of 10 per cent. nitric acid in absolute alcohol; Seed's "process plates" were used in photographing the structure; and the prints were made on glossy "Argo" paper.

It should be understood that the micrographs represent the results of treating bars of forged steel—in other words, that they do not show the effects of forging.

II. Acid Open-Hearth Steel Containing About 0.50 Per Cent. of Carbon.

1. *Structure as Related to Temperature at the Same Rate of Cooling.*

The composition of the steel was:—C, 0.55; P, 0.045; Mn, 0.66; Si, 0.25; and S, 0.032 per cent. The steel was heated in a gas-furnace to various temperatures, and immediately cooled in the air, without being held at the temperature reached. The Ac of this steel was proved to be at 710° C.

[2] "The tensile strength at first increases with the intensity of the hardening, but reaches a maximum and then declines. In the case of high-carbon steel, a moderate rapidity of cooling may give the highest tensile strength." *Iron, Steel and Other Alloys*, p. 221. On p. 268 of the same treatise, the following figures are given, among others:—

Fig. 1 shows the structure of the original forged bar, and the succeeding figures its structure after heating to the temperature stated and cooled in air, as follows: Fig. 2, to 925° C.; Fig. 3, to 650° C.; Fig. 4, to 720° C.; Fig. 5, to 750° C.; Fig. 6, to 800° C.; Fig. 7, to 850° C.; Fig. 8, to 900° C., then cooled to 550° C., reheated to 720° C., and then cooled in air, as before. The structure shown in Fig. 2 may serve as a standard, by which the effects produced by various heat-treatments can be judged.

In these micrographs, the black areas are pearlite Fe_3CFe+ (in the air-cooled specimens, sorbitic-pearlite), while the white net-work is ferrite.

The chief point brought out by a study of this series is that, until the heating has been carried past the critical point, there is no change in structure; the previous crystallization has not been broken up. But as soon as this point has been passed in the heating process, a great change takes place, and there is a new state of crystallization. After passing through Ac, the steel has become a solid solution, and when the cooling period begins, this point governs the size of the crystals; the higher above the point Ac, the coarser will be the structure. In this experiment, bars 9 in. long by 1.25 in. square were used, and the rate of cooling was therefore relatively rapid. Consequently, the various temperatures to which the steel was heated does not show marked differences, because the rapidity in cooling tends to destroy the effect of heating to a high temperature.

Fig. 8 shows that it is only necessary to let steel cool just below Ar in order that reheating may produce the same results as if the steel had been allowed to cool to the temperature of the air before reheating.

2. *Structure and Physical Tests as Related to Temperature at Different Rates of Cooling.*

The composition of this steel was: C, 0.50; P, 0.042; Mn, 0.65; Si, 0.24; S, 0.029 per cent.; and the critical point Ac was 710° C.

Figures 9 to 21, inclusive, show the structure of this steel. Figures 13 to 21, in three groups, show the effect of the different rates of cooling on the constituents of the steel. The air-cooled specimens exhibit a relatively finer structure than those

cooled more slowly. The ferrite net-work is less defined because it has been absorbed by the pearlite, in the form of sorbite.

As the rate of cooling is increased by the use of ashes or lime as a medium, the ferrite separates out more completely, and has a well-defined network, as the pearlite becomes more a lamellar combination of $Fe_3C + Fe$.

As to the physical properties, exhibited in Table I., it will be noticed that, so long as the heating has not been carried beyond the critical point, there is no marked change in tensile strength. Beginning with Fig. 13, the groups show an interesting result as regards tensile strength and percentage of elongation. As the rate of cooling has been increased, or, in other words, as the steel has been made softer, the tensile strength has declined, while the elongation has increased. In two of the groups the percentage of contraction or reduction of area has fallen, like the tensile strength.

These illustrations indicate the effect of the development of ferrite upon the tensile strength. As the ferrite has more completely separated out and become a well-defined network, it has softened the steel, thereby decreasing tensile strength and increasing the stretch.

TABLE I.—*Physical Tests of the Steel, the Structure of Which is Shown in Figs.* 9 *to* 21, *Inclusive.*

Fig. No.	Tensile Strength. Lb. Per Sq. In.	Elongation on 4-In. Per Cent.	Reduction of Area. Per Cent.	Heated to Deg. C.	Cooled in.
9	104,176	23	46	As hammered.	Air.
10	105,960	20	36	800	Air.
11	105,450	22	35	440	Air.
12	101,120	23	37	660	Air.
13	99,847	25	43	710	Air.
14	97,555	26	31	710	Ashes.
15	95,770	25	29	710	Lime.
16	109,271	21	31	780	Air.
17	101,120	22	31	780	Ashes.
18	96,026	23	33	780	Lime.
19	106,979	19	33	900	Air.
20	100,866	21	33	900	Ashes.
21	97,809	23	31	900	Lime.

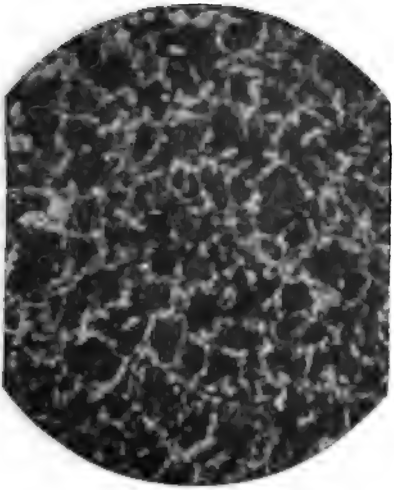

FIG. 1.
Structure of original forged bar.

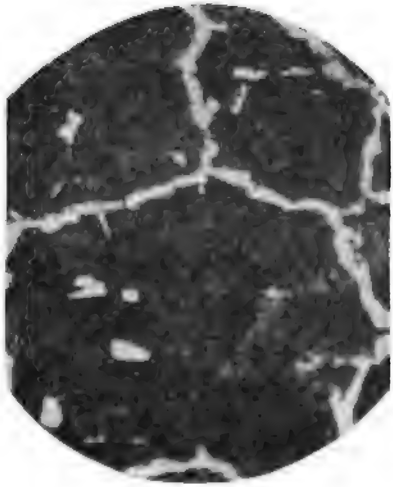

FIG. 2.
Bar heated to 925° C.

FIG. 3.
Bar heated to 650° C.

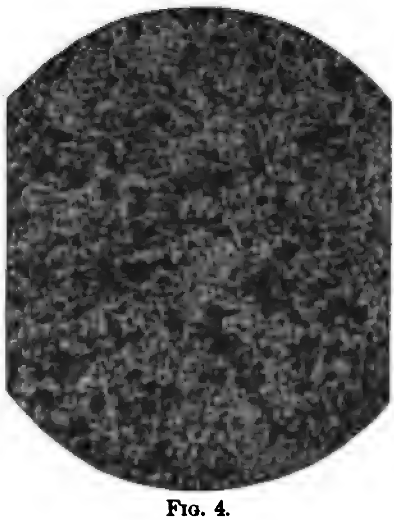

FIG. 4.
Bar heated to 720° C.

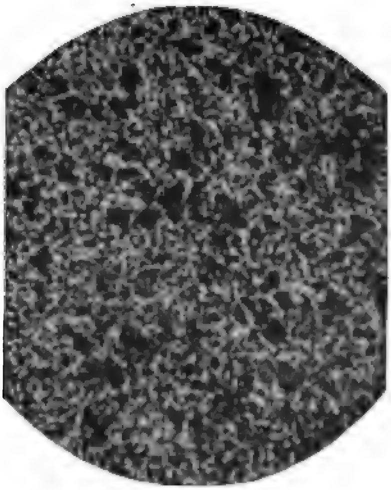

FIG. 5.
Bar heated to 750° C.

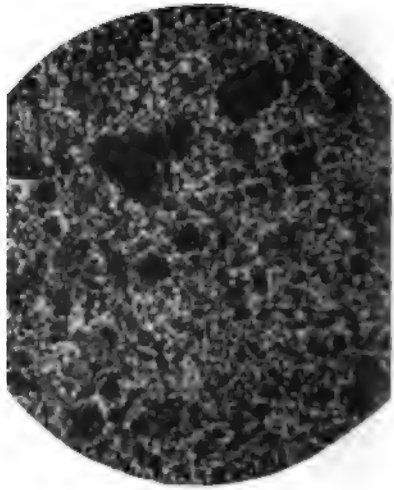

FIG. 6.
Bar heated to 800° C.

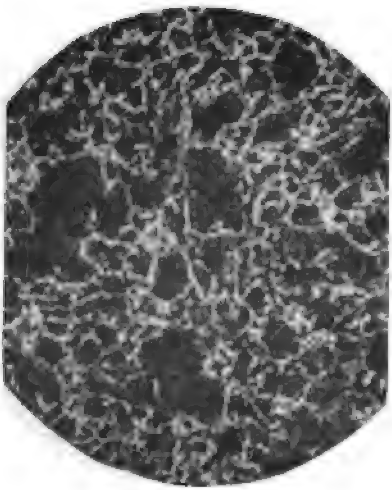

FIG. 7.
Bar heated to 850° C.

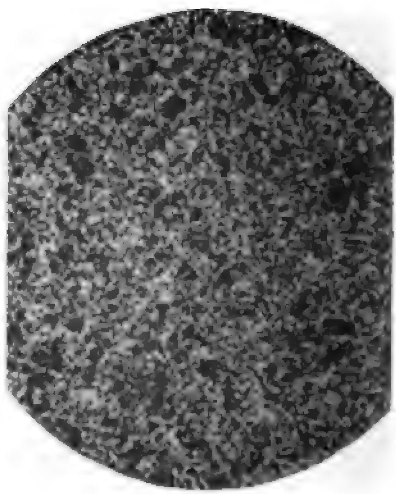

FIG. 8.
Bar heated to 900° C. and cooled to 550° C., then re-heated to 720° C. and cooled in air.

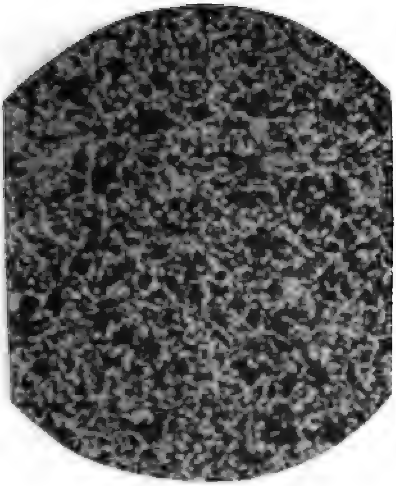

Fig. 9.
Structure of original forged bar.

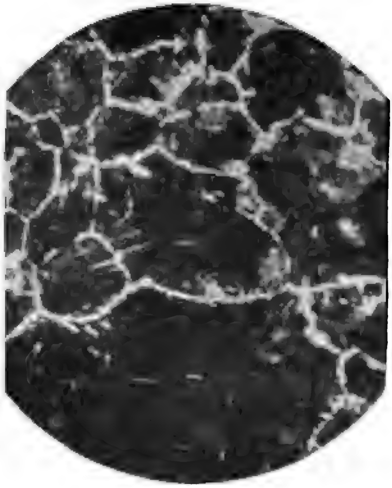

Fig. 10.
Bar heated to 800° C.; air-cooled.

Fig. 11.
Bar heated to 440° C.; air-cooled.

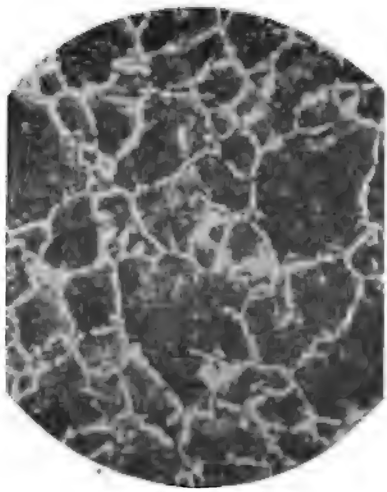

Fig. 12.
Bar heated to 660° C.; air-cooled.

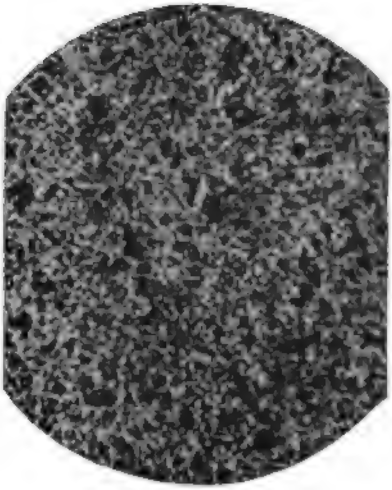

Fig. 13.
Bar heated to 710° C.; air-cooled.

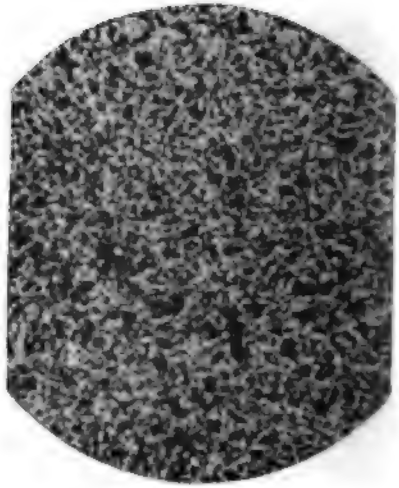

Fig. 14.
Bar heated to 710° C.; cooled in ashes.

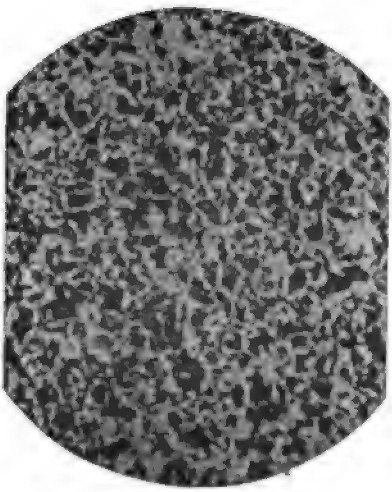

Fig. 15.
Bar heated to 710° C.; cooled in lime.

Fig. 16.
Bar heated to 780° C.; air-cooled.

Fig. 17.
Bar heated to 780° C.; cooled in ashes.

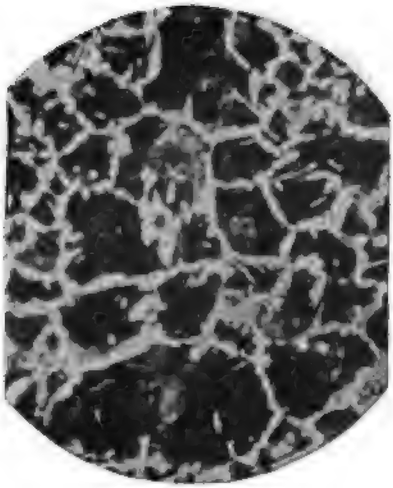

Fig. 18.
Bar heated to 780° C.; cooled in lime.

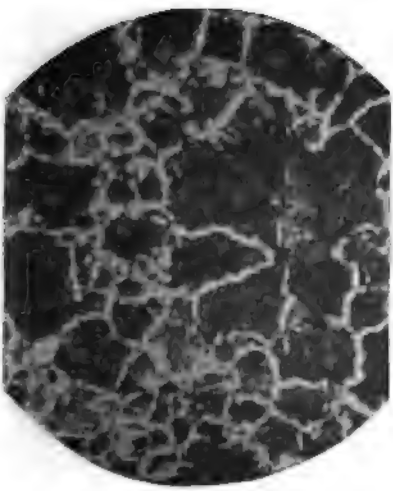

Fig. 19.
Bar heated to 900° C.; air-cooled.

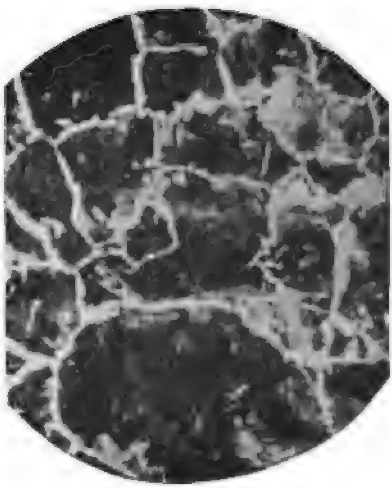

Fig. 20.
Bar heated to 900° C.; cooled in ashes.

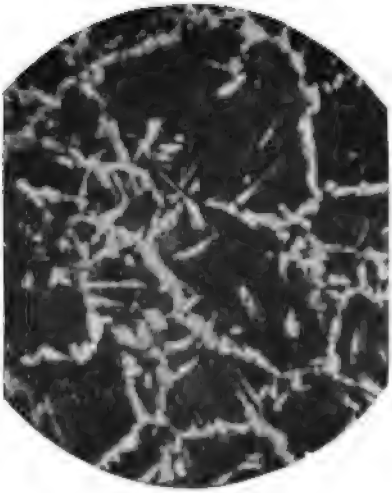

FIG. 21.
Bar heated to 900° C.; cooled in lime.

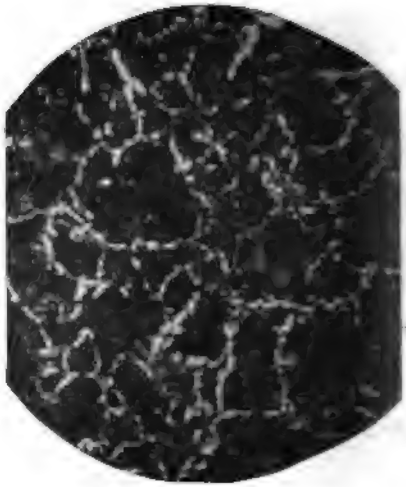

FIG. 22.
Bar hammered for 1 min. to dull yellow color; cooled in air.

FIG. 23.
Bar hammered for 1 min. to dull yellow color; cooled in lime.

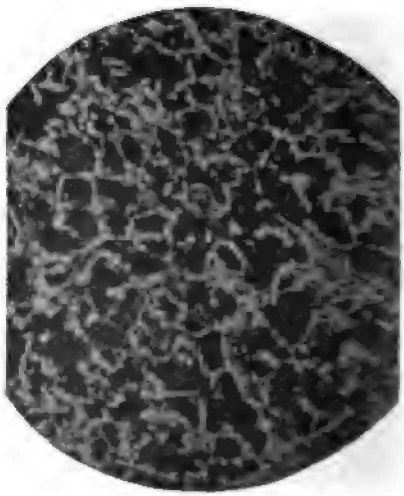

FIG. 24.
Bar hammered for 2 min. to cherry red color; air-cooled.

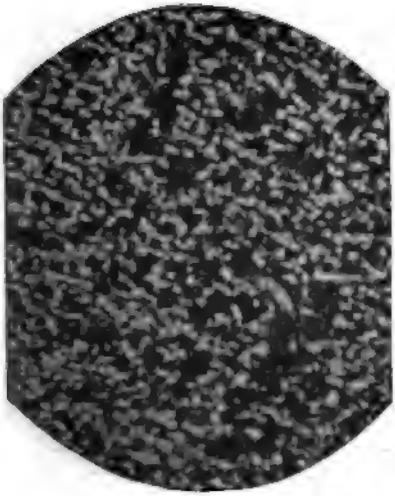

FIG. 25.
Bar hammered for 2 min. to cherry red color; cooled in lime.

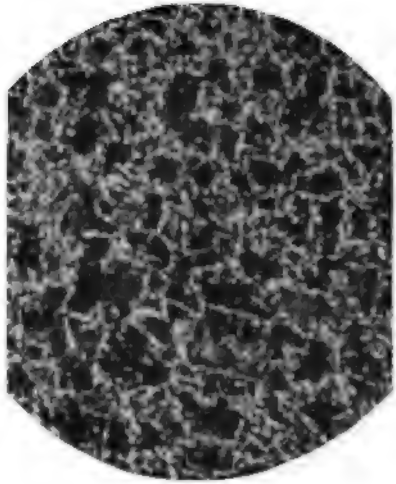

FIG. 26.
Bar hammered for 3 min. to red color; air-cooled.

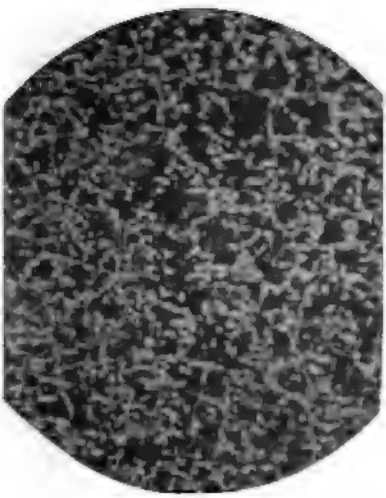

FIG. 27.
Bar hammered for 3 min. to red color; cooled in lime.

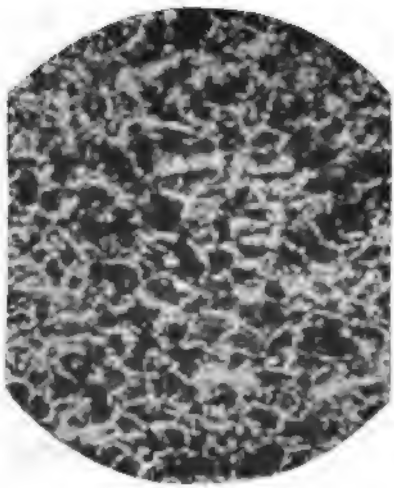

FIG. 28.
Bar hammered for 4 min. to a dark red color; air-cooled.

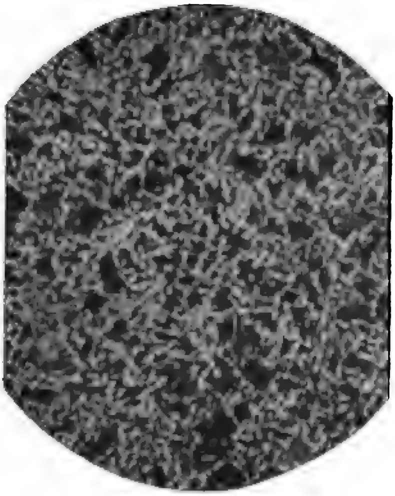

FIG. 29.
Bar hammered for 4 min. to a dark red color ; cooled in lime.

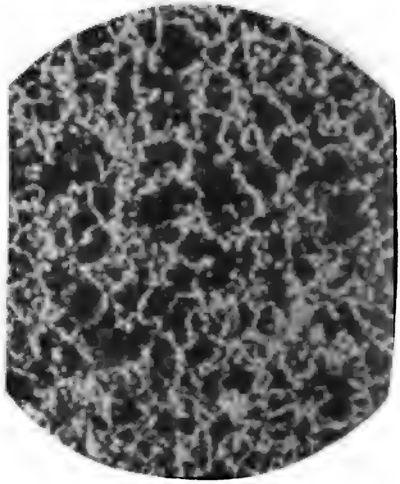

FIG. 30.
Bar hammered for about 2 min. to a cherry red (center of bar).

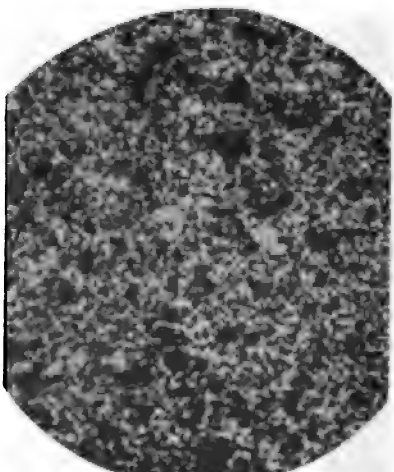

FIG. 31.
Same as under Fig. 30 ; cooled and reheated to match No. 30 as it left the hammer (center of bar).

3. *Structure and Physical Properties as Related to Different Finishing-Temperatures and Different Rates of Cooling.*

This steel contained: C, 0.52; P, 0.034; Mn, 0.65; Si, 0.24, and S, 0.029 per cent. Bars, 12 in. long by 1.25 in. square, were drawn from test-ingots 4 in. square, which had been previously cogged under a steam-hammer, all these ingots having been heated to 1,000° C. (the temperature of the furnace) before work was begun. Since the finished bars were so small in section that cooling would be, in any case, comparatively rapid, only two rates of cooling were tried, namely, that of cooling in lime, and that of cooling in air within a lined box, which simply protected the bar from drafts of air in the shop. The temperature in this box was about 100° F.

The work was measured by time, since the smith hammered the bars under a small steam-hammer, giving about the same blows to each bar, without any knowledge of what the experimenter had in mind.

TABLE II.—*Physical Tests of the Steel, the Structure of Which is Shown in Figs. 22 to 29, Inclusive.*

Fig.	Cooled in.	Time of Work. Min.	Color.	Tensile Strength. Lb. Per Sq. In.	Elongation on 4-In. Per Cent.	Reduction of Area. Per Cent.
22	Air.	1	Dull yellow.	107,997	17.5	33
23	Lime.	1	....	95,515	18.0	31
24	Air.	2	Cherry red.	104,940	16.0	36
25	Lime.	2	....	93,988	18.5	36
26	Air.	3	Red.	103,375	18.0	37
27	Lime.	3	....	94,498	21.0	39
28	Air.	4	Dark red.	100,865	17.5	36
29	Lime.	4	....	99,083	20.0	39

As in the preceding group, the effect of the lime-treatment, allowing a thorough separation of the ferrite from the mother metal, lowered in every case the tensile strength, so, conversely, by cooling at a quicker rate in the box, the tensile strength has been raised. The difference becomes greater as the cooling-period is lengthened by a higher finishing-temperature, as indicated by the smaller amount of work done upon the bar before cooling. The same marked decrease in tensile strength with continued work and consequent lower finishing-temperature is not exhibited by the lime-cooled specimens (Nos. 23, 25, 27 and 29). The large increase in tensile strength, shown in No. 29,

may possibly be due to an accidental longer exposure to air (by reason of slower handling, stamping, etc.) between the finish of the work and the immersion in lime. This would have allowed air-cooling to affect the result.

There has been a notion at some steel-works that, the hotter a bar is finished, the lower will be its tensile strength. This experiment disproves that proposition, confirming, so far as it goes, the well-established theory that tensile strength increases, up to a certain point, with finishing-temperature. Beyond that point (which, however, was not passed in this experiment) it decreases.

4. *Prof. Sauveur's Statement.*

To test this statement (quoted in a footnote above), two bars were drawn from the ingot of the composition, shown in Table II. The first was drawn in the usual way (the work occupying about 2 min.), and cooled in the air. When cold, it was re-heated in a coke-furnace to cherry-red; and at the same time the second bar was hammered from the hot ingot until it was cherry-red (about 1,350° F.). When work ceased on this bar, the other was drawn from the furnace. Even to the experienced eye of a heater, there was no difference in appearance; both seemed to have the same temperature. They were then cooled, side by side, in a lined box. Fig. 30 shows the resulting structure of the bar finished at cherry-red, and Fig. 31 that of the bar re-heated to cherry-red. The latter is easily seen to be finer, showing that the identical outside appearance of the two bars was misleading as to their internal condition. The center of the worked bar was higher than that of the re-heated one. It is not possible to produce the same effect by work as by re-heating; for work preserves (and, if it be severe enough, even raises) the internal temperature, and subsequent cooling sets up an unequal crystallization. Under proper re-heating, on the other hand, the steel becomes a solid solution, from which crystals of approximate homogeneity and uniform size may separate.

Table III. shows a difference in physical qualities corresponding to that of the structure. The same difference is observed when larger masses of steel are similarly treated.

TABLE III.—*Physical Tests of Bars, of Which the Structure is Shown in Figs. 30 and 31.*

Fig.	Treatment.	Cooled in.	Tensile Strength. Lb. Per Sq. In.	Elongation on 4-In. Per Cent.	Reduction of Area. Per Cent.
30	Hammered about 2 min. to cherry-red.	Box.	109,271	15	26
31	Ditto; then cooled and reheated to match No. 30 as it left the hammer.	Box.	106,271	15	33

Prof. Sauveur's statement may be approximately correct for a very small section; but as the metallic mass treated is increased, the greater becomes the discrepancy of internal conditions which invalidates his proposition.

III. ACID OPEN-HEARTH STEEL CONTAINING ABOUT 0.75 PER CENT. OF CARBON.

In the report of this part of the series of experiments, the structure will not be shown by micrographs. Such illustrations of the structure of an "æolic" or "eutectic" steel are not easily interpreted at a glance, and would in this instance add nothing important to the evidence of the physical tests. We may, however, assume that the structural changes are analogous to those produced by the same treatment in 0.50 = carbon steel; and, for the purpose of comparison, the numbers of the corresponding sections of that material are given in parenthesis in the tables below.

1. *Physical Properties as Related to Temperature at Different Rates of Cooling.*

The composition of this steel was: C, 0.72; P, 0.034; Mn, 0.64; Si, 0.22; S, 0.03

TABLE IV.—*Physical Tests of Bars Nos. 32 to 44, Inclusive.*

Bar No.	Tensile Strength. Lb. Per Sq. In.	Elongation on 4-In. Per Cent.	Reduction of Area. Per Cent.	Heated to Deg. C.	Cooled in.
32 (9)	143,657	13	21	As hammered.	Air.
33 (10)	139,073	11	15	300	Air.
34 (11)	124,554	13	19	440	Air.
35 (12)	136,526	11	15	660	Air.
36 (13)	129,139	9	23	710	Air.
37 (14)	123,535	14	21	710	Ashes.
38 (15)	113,092	15	19	710	Lime.
39 (16)	131,176	12	17	780	Air.
40 (17)	131,686	9	18	780	Ashes.
41 (18)	126,816	11	15	780	Lime.
42 (19)	129,393	7	23	900	Air.
43 (20)	117,677	11	15	900	Ashes.
44 (21)	119,205	9	10	900	Lime.

These results do not give as regular or as conclusive figures as those obtained from the 0.50 = carbon steel; but it appears upon careful study of them that as the rate of cooling increases, the tensile strength and the contraction decrease, while there is a slight rise in elongation.

Although, as already explained, the experiments were made upon bars 1.25 in. square, and therefore can serve only as indications of what would take place in larger masses, it has been found in practical experience that these indications are highly trustworthy, and that the behavior of large masses of steel under similar conditions follows the same law.

2. *Physical Properties as Related to Different Finishing Temperatures and Different Rates of Cooling.*

This steel had the same composition as that of Table IV.

TABLE V.—*Physical Tests of Bars Nos.* 45 *to* 56, *Inclusive.*

Bar No.	Treatment. Drawn to.	Time. Min.	Cooled in.	Tensile Strength. Lb. Per Sq. In.	Elongation on 4-In. Per Cent.	Reduction of Area. Per Cent.
45	Dark red.	4.5	Air.	131,431	11.0	19
46	Dark red.	4.5	Box.	130,667	11.0	19
47	Dark red.	4.5	Ashes.	131,176	10.0	23
48	Red.	3	Air.	133,978	11.0	23
49	Red.	3	Box.	131,940	11.0	23
50	Red.	3	Ashes.	125,837	12.0	23
51	Cherry-red.	2	Air.	139,837	9.0	19
52	Cherry-red.	2	Box.	136,271	10.0	17
53	Cherry-red.	2	Ashes.	128,371	11.5	19
54	Dull yellow.	1	Air.	139,327	8.5	19
55	Dull yellow.	1	Box.	138,383	10.5	19
56	Dull yellow.	1	Ashes.	Broke in machine.		

3. *Prof. Howe's Statement.*

This statement, quoted in a foot-note on a preceding page, is confirmed by our experiments. Table V. clearly shows an increase of tensile strength with increase of finishing-temperature. (Compare Nos. 46, 49, 52 and 55.) Table II. gives similar evidence. Tables VI. and VII. furnish further direct corroboration.

TABLE VI.—*Physical Tests of Steel Containing:* C, 0.76; P, 0.031; Mn, 0.64; Si, 0.26; S, ——.

Bar No.	Treatment. Drawn to.	Time. Min.	Cooled in.	Tensile Strength. Lb. Per Sq. In.	Elongation on 4-In. Per Cent.	Reduction of Area. Per Cent.
57	Dark red.	4.5	Box.	139,078	10	15
58	Red.	3.0	Box.	141,619	10	14
59	Cherry-red.	2.0	Box.	142,638	9	19
60	Dull yellow.	1.0	Box.	142,929	9	15

TABLE VII.—*Physical Tests of Steel Containing:* C, 0.74; P, 0.033; Mn, 0.66; Si, 0.28; S, ——.

Bar No.	Treatment. Drawn to.	Time. Min.	Cooled in.	Tensile Strength. Lb. Per Sq. In.	Elongation on 4-In. Per Cent.	Reduction of Area. Per Cent.
61	Dull yellow.	1	Box.	137,544	9	17
62	Cherry-red.	2	Box.	136,526	10	17
63	Red.	3	Box.	136,271	11	19

IV. CONCLUSIONS.

These experiments have shown that, with one exception, the theories based by investigators of acknowledged authority upon experiments with other grades of steel hold good as to the two classes of acid open-hearth steel here considered. Indeed, with regard to the one exception—namely, the qualified contradiction of Prof. Sauveur's statement as to the relative effect upon structure of mechanical work and heat-treatment—it may fairly be claimed that while the observations adduced as evidence were made upon a certain kind of steel only, the explanation which they demand is equally applicable to all other kinds, so far as their structure is affected by work or by heat-treatment. In this particular, the experiments simply declare what we would naturally expect, as an inference from the physical circumstances.

It may therefore be confessed that these experiments have done no more than bring certain commercial steels into line with others, more thoroughly investigated heretofore, in support of generally accepted theories as to heat-treatment. Yet, on the other hand, it may be asserted that such a confirmation is by means wholly superfluous or useless. Even theorists welcome direct evidence in support of generalizations based upon analogies, or partial indications; and practitioners are prone to think (not always without some justification) that the

special problems with which they have to deal are not to be solved by formulas calculated from different data. It is no small thing to convince a practical mill-man of a really general law, which governs his mill, as well as others.

I may add that, in actual practice, the results of the above experiments, and others like them, have proved highly useful as checks upon daily operations, guides to needed improvements in manipulation, and suggestions of remedy for difficulties encountered. It is not only the practical experts who may profitably realize the value of scientific inquiries and their results. The proprietors of works (including the directors and stockholders of manufacturing corporations) might well appreciate more highly the advantage of such inquiries, made by their own employees and at their own expense. Everybody has arrived (though only in comparatively recent years) at the recognition of the indispensable value of a chemical laboratory in connection with every ironworks. It cannot be said that the science of metallography has yet achieved a similar recognition. But the time is not far off when this science also will be welcomed as an aid by an industry which unquestionably needs all the scientific help it can possibly get.

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

A New Colorimeter for the Determination of Carbon in Steel.

BY CHARLES H. WHITE, CAMBRIDGE, MASS.*

(London Meeting, July 1906.)

METHODS in colorimetry are based on the assumption that the intensity of the color of a definite volume of solution is directly proportional to the quantity of the color-producing substance present. In the preparation and examination of colored solutions there are three ways in which the depth of color may be varied. These variables are; (1) the quantity of the coloring matter, (2) the quantity of the solvent, or the dilution, and (3) the thickness or depth of that portion of the solution examined. With these three variables as a basis, three general methods in colorimetry have been devised, all of which have been used in the determination of carbon in steel.

In the first method, the quantity of the solution is kept the same for both the unknown steel and the standard, and the sections compared are of equal thickness, while the quantity of the standard is varied until the color obtained is of the same intensity as that produced by a definite quantity of the unknown steel. In laboratories where this method is used there is prepared and kept for permanent use a series of solutions with varying amounts of the standard, representing the percentages of carbon from the lowest to the highest demanded in that laboratory. These standard solutions are kept in bottles, or test-tubes of equal diameter, and are arranged in series from the faintest to the most intense color, so that it is a simple matter to find the place of the unknown steel in the series, when the solution is of a definite volume and is contained in a tube of the same diameter as the standard tubes.

In the second method, equal quantities of the standard and of the unknown steel are dissolved, the standard is diluted to a definite volume, and the solution of the unknown steel is di-

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luted until the colors are of equal intensity in sections of equal thickness. This method is usually carried out by dissolving equal quantities of the two steels in equal volumes of dilute nitric acid, and then diluting in long graduated test-tubes of equal diameter until the colors agree when the light passes through the tubes at right angles to their length. The percentage of carbon in each is then proportional to its volume.

In the third method, equal quantities of the two steels are dissolved in equal volumes of the solvent, and the thickness or depth of the solutions under examination is varied until the colors are the same. The percentage of carbon is then inversely proportional to the thickness of the section. This method has been applied to the determination of carbon in steel by pouring varying amounts of the two solutions into long graduated test-tubes with flat bottoms, until the colors are of equal intensity when viewed longitudinally from above, the source of light being below the tubes.

Each of these methods has excellent points to recommend it; but, as is well known to experimenters in colorimetry, there are serious objections to all of them, as they have hitherto been applied in practice. In the application of the first method, it seems almost impossible to obtain permanent standards. It is not practicable to keep on hand standards for a wide range of steels; and the standard for one kind of steel will not serve as a standard for a steel of a different kind, or for one that has been subjected to a different treatment. The strongest objection to the second method is the necessity for repeated dilutions by guess, mixing and comparing until the correct volumes are more or less accidentally hit upon. Moreover, if the graduation of the tubes is not marked in such a manner as to correspond in numerical value to the hundredths per cent. of carbon present, there is a loss of time in arithmetical calculations. For the third method, the difficulty of obtaining satisfactory apparatus has been serious. A moderately long tube having a flat bottom, with true plane surfaces at right-angles to the axis, is made with great difficulty; and if the apparatus is so constructed that the depth of the solution may be increased or diminished conveniently, the emptying and cleaning after each determination renders manipulation necessarily slow.

The colorimeter here described was designed for the rapid

and accurate application of the third method, and has proved itself free from many of the objections belonging to those previously devised. In this method, equal quantities of the standard and of the unknown steel are dissolved in equal volumes of the solvent, diluted to a definite volume, and varying thicknesses of the solutions compared until the colors agree; then the ratio of the thickness of the two solutions compared is inversely pro-

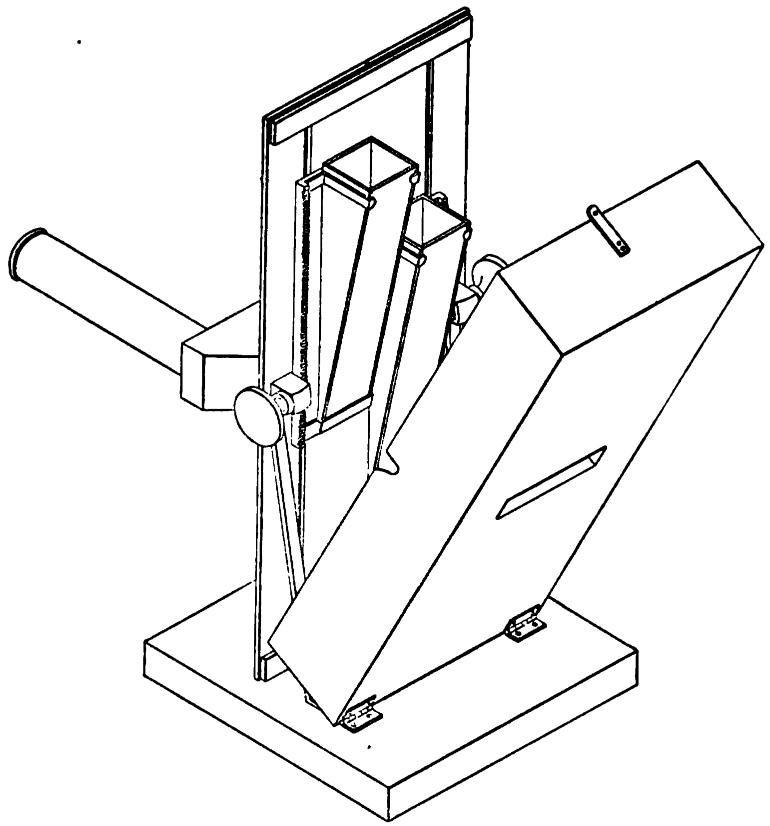

FIG. 1.

portional to the percentages of carbon present. In using this apparatus, the two steels, the standard and the unknown, are dissolved in the usual manner in large test-tubes, diluted to equal volume, indicated by a mark on the tubes, and the solutions are compared in hollow glass wedges. The wedges must be of equal angle, and it is convenient to have them as nearly as possible of equal size. The large end is left open for the in-

troduction of the solutions, and they are mounted side by side in a vertical position for comparison. Each wedge may be raised or lowered by means of a thumb-screw, carrying a pinion which engages with a rack holding the wedge. (See Figs. 1 and 2.) The wedges are encased in a box, which is provided with a narrow horizontal aperture in both the front and back,

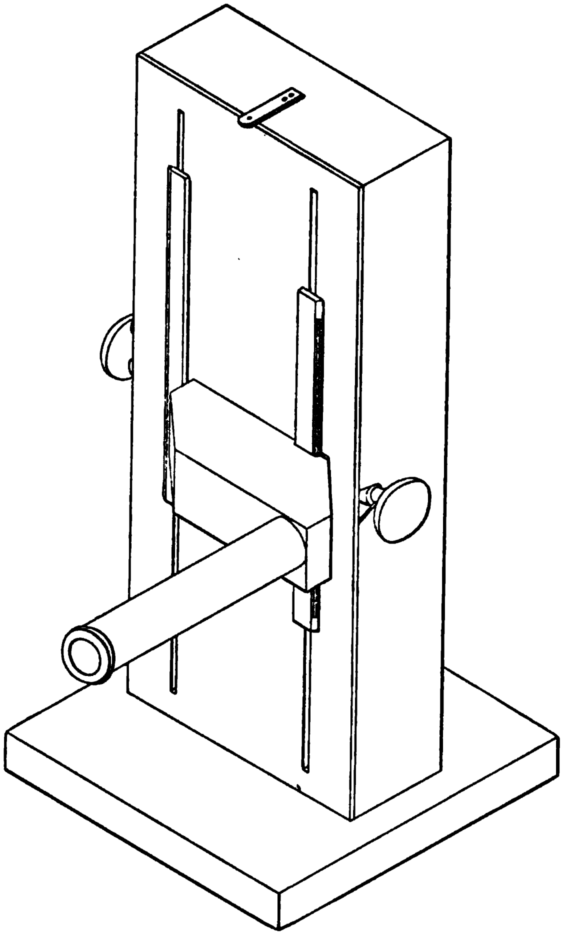

FIG. 2.

admitting of the direct passage of the light through the wedges in this zone only. In front of the aperture, or slit, are three mirrors, shown in Fig. 3, arranged in such a manner as to render the comparison of the colors easy and exact. The band of color, as observed in mirror, *C*, through the tube, *T*, is composed of three nearly-equal parts. The central portion is the

color of the solution in wedge, *S*, reflected from mirror, *A*, through that portion of mirror, *B*, from which the silver has been removed. The outer portions of the band of color are from wedge, *U*, and are reflected from the silvered portions of mirror, *B*. The racks which carry the wedges carry also graduated scales on the front of the instrument, which show, in every position, the distance from the sharp edge of the wedge to the slit where the comparison is being made. Uniform illumination is secured by admitting the light to the solutions through a pane of ground-glass, shown in section in Fig. 3.

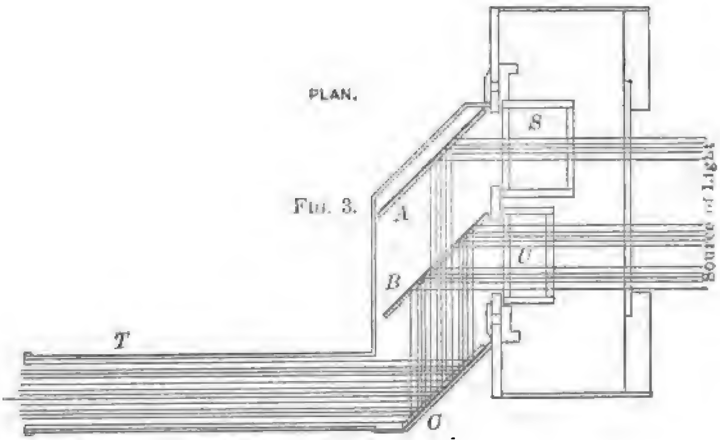

FIG. 3.

In operating this instrument, if the wedges are so adjusted that the colors are of equal intensity, and if their thickness at the slit—the point of comparison—is determined, or the ratio of one to the other is known, it is easy to calculate the percentage of carbon in the unknown steel. Since a longitudinal vertical section of one of these wedges is triangular and equal in all respects to a similar section of the other wedge, we are not restricted to the measure of the thickness of the solutions to determine the desired ratio, but the length of each from its sharp edge to the point compared may be read off on its graduated scale and used instead.

Suppose, for example, the standard steel has 0.30 per cent. of carbon, and, after the wedges have been adjusted by means of the thumb-screws until the colors match, it is found that the scale on the side of the standard reads 72 and the scale of the

other wedge reads 60; then the proportion ($60:72 = 0.30:x$) shows that the percentage of carbon in the steel under examination is 0.36. But the solutions in the wedges may be as easily compared at the graduations 30 and 36 as at 60 and 72; and if the scale on the side of the undetermined steel is set at 30 and the other wedge, carrying the standard, is adjusted until the colors are equal, then its scale must read 36,—the desired figure.

It is obvious that with this instrument we may vary the standard at will from the highest to the lowest in carbon, and also avoid the difficulties attending attempts at permanent standards; the haphazard diluting required in the second method is obviated, while the wedges are as easily emptied and filled as test-tubes. The chief advantages, however, derived from the use of this instrument are the speed and accuracy with which the colors are matched, and the fact that the percentage of carbon is read off directly.

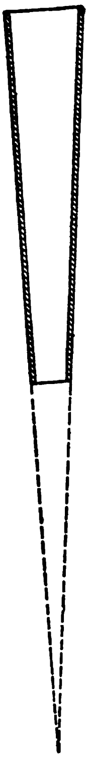

FIG. 4.

With respect to the best form of wedge, it is evident that, other things being equal, the accuracy of the instrument increases as the angle of the wedge diminishes. But very thin sections of colored solutions are not easily matched, and long wedges are unwieldy and in many ways objectionable. It is not necessary, however, to use the whole length of the wedge; for the standard and the unknown steel can not differ greatly in the amount of carbon contained, nor therefore in the colors produced when in solution. The wedges, then, may be designed to have any suitable angle, and only so much of the large end need be used as will afford the range desired. In other words, the wedges are cut off, the lower end of the upper portion sealed, and the lower part discarded, as shown in Fig. 4. The scales, however, must be graduated to accord with wedges of the full length. Wedges of this type are useful for the most exact colorimetric work, but with the ordinary size shown in the instrument in Fig. 2, comparisons are quickly made and read with accuracy to the second decimal place, which is as accurate as other parts of the color-method for carbon in steel can be relied upon to be.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

A Device for Regulating the Discharge of Water from a Reservoir.

BY P. BOUÉRY, WEAVERVILLE, CAL.

(London Meeting, July, 1906.)

THIS account of a contrivance which has been found serviceable in practice may be of interest to engineers, and especially to those engaged in hydraulic mining.

In that process, one feature which seems at first sight to possess little significance, is highly important in its effects, namely, the regular supply of water to the "giants." The chief condition of this regularity is an even flow in the pipe-line from the penstock to the nozzle. This, of course, requires that the penstock be kept full. Any considerable surplus of water, overflowing at the penstock, is a simple waste, unless it be otherwise utilized in the sluices. At all events, it does not affect the delivery of the nozzles. But a deficiency at the penstock may admit air into the pipe; and this may produce hydraulic recoil, injuring the line by incessant vibrations, giving rise to leaks, and even to blow-outs, and (when a partial vacuum exists at the time of the fracture) the collapse of the pipe.

An accident of this sort in our main pipe-line, occasioned partly by a settling of the ground and partly by the presence of air in the pipe, led to the employment of the device here described. The line referred to is made of 30-in. pipe, successively reduced to 18 and 15 in. in diameter, for the supply of two giants. By reason of the causes above mentioned, the 30-in. pipe burst more than 1,400 ft. from the penstock, and, despite the air-valve, the 30-in. pipe was collapsed to such a degree that one length of it, next to the penstock, was squeezed together and positively swallowed by the main pipe, through which it traveled for 750 ft., piercing through a short elbow on the way.

This remarkable result was undoubtedly the effect of the vacuum suddenly produced when the pipe burst.

Aside from the dilatation and contraction due to changes in temperature, and changes in the ground itself (all of which, except earthquakes, should be prevented by suitable care in construction), a pipe-line, properly laid, is exposed to no other cause of injury than the action of air mixed with the water, which, by reason of the difference of the two in specific gravity, produces variable and unequal strains in the pipe.

At every hydraulic mine, a reservoir is interposed, if practicable, between the ditch and the pipe-line to the giants, for the storage and proper utilization of the water. When this reservoir is full, and the giants are ready to be operated, the gate-tender opens the main gate of the reservoir just enough to supply the giants and give a little overflow at the penstock, to prevent the entry of air. If the supply to the reservoir is smaller than the discharge thus permitted, the consequent lowering of the water-level in the reservoir reduces the hydrostatic pressure at the discharge-opening, and therefore the rate of discharge. To counteract this effect, the gate-tender raises the gate so as to compensate by greater area the diminished pressure; and this process is continued until the reservoir is almost empty.

This method of regulating the supply of water to the giants evidently leaves the whole matter to the vigilance and skill of one man, who, however faithful in the main, cannot be expected to prevent, or even to be able to prevent, irregularities in the working-supply. If he raises the gate either a little too high, or a little too late, the result is in one case an unnecessary loss of precious water through excessive overflow, or, in the other case, the entrance of air into the pipe-line, with consequent injurious vibrations.

We have found that this source of irregularity can be removed, while, at the same time, the wages of one man for both the day- and the night-shift could be saved, by utilizing the water in the reservoir itself to furnish a hydraulic head sufficient to operate automatically and continuously, a little auxiliary gate (independent of the main gate), and thus maintain the small overflow at the penstock, needed to prevent the entrance of air. The device adopted for this purpose is shown in Fig. 1. This sketch is not drawn to scale, but it will sufficiently illustrate the following description:—

1. In the dam of the reservoir, we cut a second outlet, of appropriate size, at the level of the main gate.

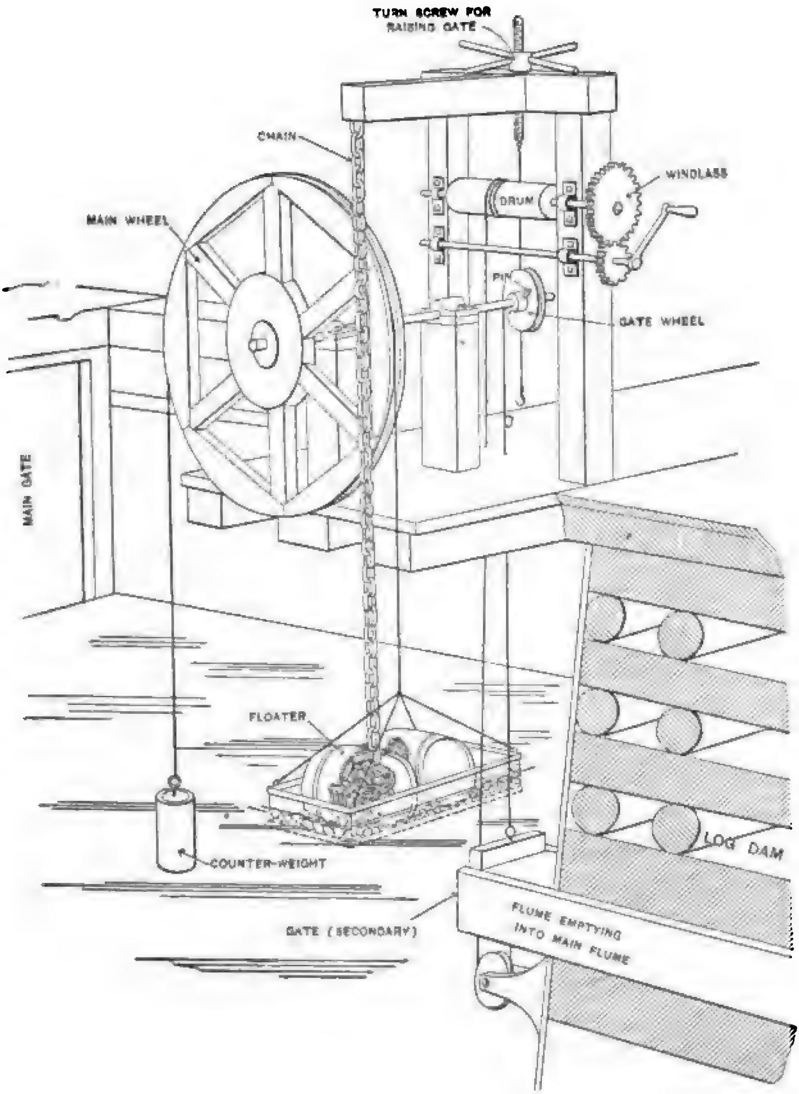

FIG. 1.—SKETCH OF AUXILIARY APPARATUS FOR REGULATING THE DISCHARGE OF WATER.

2. On the top of the dam we set up a large wheel, with grooves for two small cables, wound in opposition, and supporting respectively a floater and a counter-weight.

3. On the prolongation of the shaft of the main wheel we fixed a smaller "gate-wheel," of relative diameter duly calculated, carrying a cable, attached at its lower end to a secondary gate, opening a flume emptying into the main flume. This cable moves in a direction the reverse of the cable which is carried by the main wheel, and supports the floater. The small gate-wheel is loose on the shaft, but can be made, by means of a pin passing through hub and shaft, to revolve with the main wheel.

4. Under the small secondary gate we placed another wheel, around which passed a cable (attached at one end to the bottom of the said gate, and at the other end to the drum of a windlass above).

5. Finally, above the small gate-wheel, we placed a turnscrew, by means of which the small secondary gate could be raised independently of the automatic operation of the apparatus. It is evident that, as the floater suspended from the main wheel falls with the water-level in the reservoir, the consequent revolution of the gate-wheel will raise the secondary gate, and thus increase the amount of water discharged at a lower head. The proper relation of this compensating increase is determined by the relative diameters of the two wheels, of which more will be said presently.

6. When the reservoir is full, the main gate is raised, and the small gate-wheel is pinned to the main shaft. If the water leaves the reservoir in excess of the supply, the consequent lowering of the water-surface will depress the floater, turning the main wheel, and with it the small gate-wheel. Both the cables concerned will be in high tension: one supporting the descending floater; the other raising the secondary gate; consequently, neither can, under ordinary circumstances, fail to operate. Moreover, there is no sudden change of the aperture of the secondary discharge, which is increased proportionally to the gradual descent of the floater, until the reservoir is empty. When this has taken place, the small gate-wheel is loosened by the removal of the pin; the secondary gate is closed by means of the windlass; and, the main gate being also closed, the reservoir is allowed to fill again. During this process, the cable supporting the floater is kept in tension by the counter-weight.

It is easy to calculate for each case the pressure on the small gate to be overcome, and the force required to overcome it in raising that gate; the ratio of diameters between the main wheel and the auxiliary gate-wheel, required to secure the necessary leverage; and the size and weight of floater required to overcome all frictions and raise the small gate. In this operation, however, the strain is greatest at the beginning, and diminishes to a minimum at the end. This variation is counteracted, and the water-line is kept at about the same place during the raising of the gate, by means of a heavy chain, hung above the floater, and long enough to reach it when the water is very low. As the floater descends, the amount of chain carried by it decreases, to the extent required for a uniform action.

The calculation of the size of the auxiliary gate can be easily made when the reservoir is regular in shape. But for a reservoir of complicated form, the necessary data must be obtained by observation and measurement. For this purpose the rise of the main gate is noted every fifteen minutes after the start. The width of the gate and the amount of each rise are the sides of the rectangle for the opening. By combining these periodic observations, the total area of the main gate-opening is obtained; and the size and form of the small gate-opening can be planned with sufficient accuracy.

The cost of the material of this device does not exceed $100. In fact, we used an old Pelton wheel, enlarged in diameter to 8 ft., with a rim made of planks for the grooves. The floater was made with two empty barrels attached to a frame supporting a box full of boulders. Some old pieces of chain, welded together, with a pulley and a windlass as the only new material, completed the system.

The results obtained thus far have saved us the wages of one man (by enabling one tender to do the work formerly requiring two), and 50 per cent. of the cost of keeping up the pipe-line. Some better arrangement might be made, but it would probably be much more expensive, and this process may be of some value in remote countries where cheap installations are required. We are satisfied that the device could be made simpler in construction. Its installation was intended only as an experiment; but its operation has been so satisfactory that the temporary structure has become final.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Tin-Deposits of the Kinta Valley, Federated Malay States.

BY WILLIAM R. RUMBOLD, ORURO, BOLIVIA, SO. AMERICA.

(London Meeting, July, 1906.)

THE Kinta valley in the State of Perak, one of the largest of the Federated Malay States, is probably at the present time the richest alluvial tin-district in the world, Perak producing from 20,000 to 25,000 tons of tin annually, and the Kinta valley being the chief producer.

The valley runs approximately north and south, and is 30 miles long by 12 wide. It is very flat, the mountain-ranges on either side rising abruptly from the plain, that on the east being the great Central range of the peninsula, and that on the west a subsidiary range marked "Kledang" on the map, Fig. 1.

The valley is drained by the Kinta river, which rises in the eastern mountain range and flows south to join the Perak river, being joined by numerous streams from both mountain-ranges.

The rain-fall is heavy, averaging annually about 90 in. The whole country is covered with dense jungle, except where it has been cleared for mining-operations and a small amount of cultivation.

Mining villages are scattered throughout the valley, the chief towns being Kampar, Batu Gajah, Lahat and Ipoh, the latter being the center of the mining-operations.

An ideal section of the main geological features of the Kinta valley is given in Fig. 2. The valley is composed of a highly crystalline limestone, usually white in color, sometimes gray; in fact, it may be called marble. It is always highly inclined and often contorted, and in some places is interbedded with shale. On the east side of the valley, near its contact with the granite, it forms a remarkable series of limestone cliffs, which rise in some cases as high as 2,000 ft. above the level of the limestone in the valley. It is non-fossiliferous, and its geo-

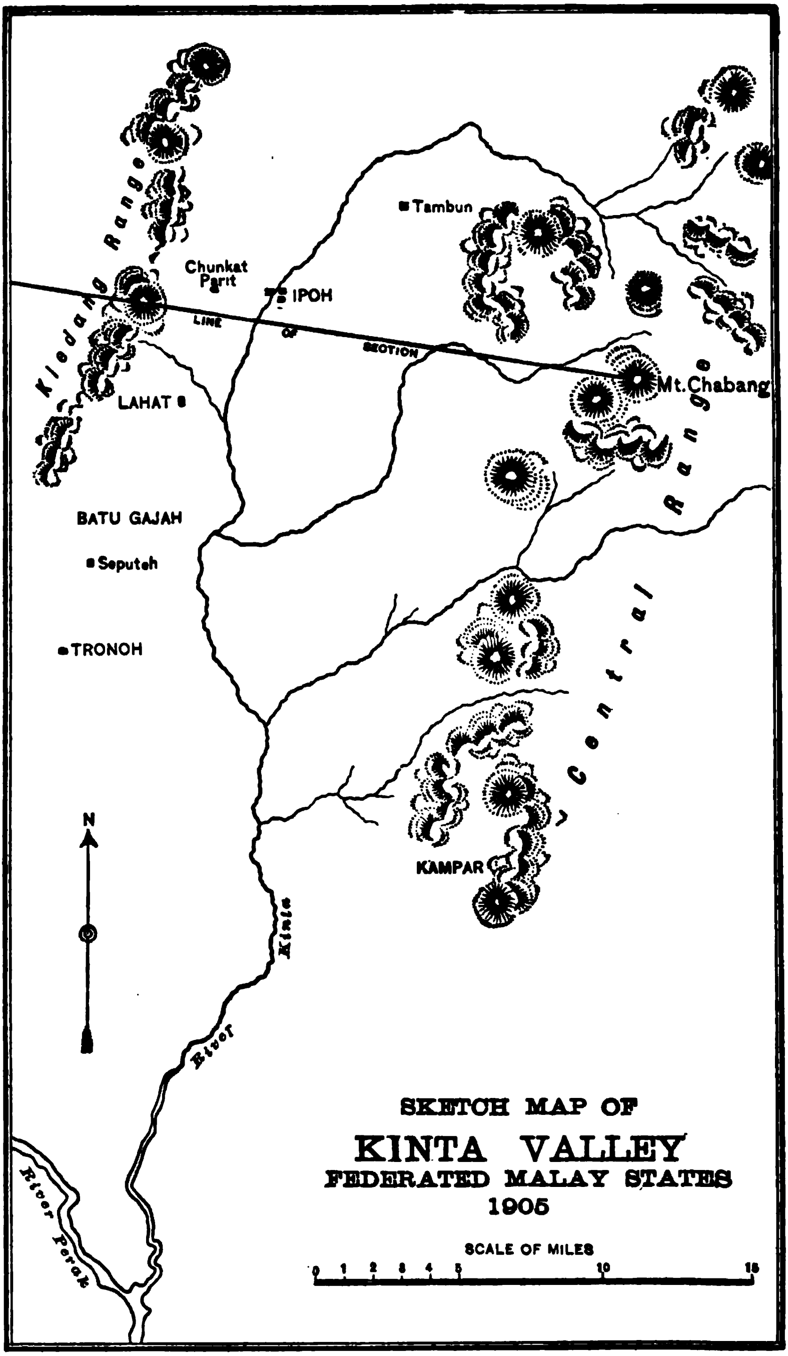

FIG. 1.—SKETCH MAP OF THE KINTA VALLEY, FEDERATED MALAY STATES.

logical age is unknown. The mountains on both sides are composed of granite, which is intrusive and has doubtless been the cause of the contortion and metamorphism of the limestone, the latter appearing as though it had been squeezed between the two intrusive masses. The granite is gray in color, and often porphyritic, with large, well-formed crystals of orthoclase-feldspar, quartz, and biotite-mica. Tourmaline is very common.

The whole valley and a large proportion of the mountain slopes are covered with alluvium, which reaches a depth of 200 ft., as proved by mine-workings, and may be deeper in the middle of the valley, where there are very few workings; the average depth is about 30 ft. This alluvium is composed of

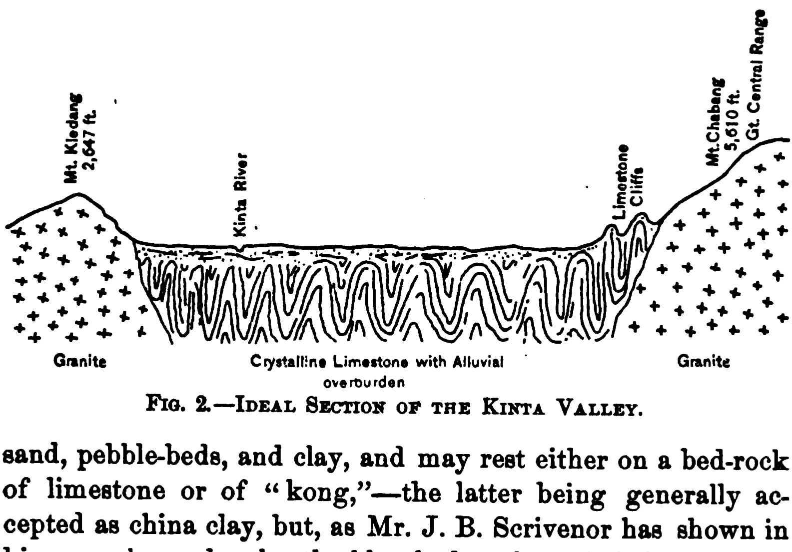

FIG. 2.—IDEAL SECTION OF THE KINTA VALLEY.

sand, pebble-beds, and clay, and may rest either on a bed-rock of limestone or of "kong,"—the latter being generally accepted as china clay, but, as Mr. J. B. Scrivenor has shown in his paper,[1] may be also the bleached surface of shales.

The limestone, from its steep bedding-planes and contorted structure, has been weathered to a very irregular surface, forming numerous little pinnacles and depressions, the latter often extending into cracks of 10 to 20 ft. in depth, the whole forming an ideal series of natural riffles.

ALLUVIAL TIN-DEPOSITS.

The alluvial tin-deposits are exceedingly variable, following no well-defined "lead;" the "karang" (tin-bearing wash) may

[1] *A Preliminary Report on the Geology of the Neighborhood of Taiping.* (Published as *Supplement to the "Perak Government Gazette,"* Jan. 15, 1904.)

be sandy, or the tin may be carried in a thick, heavy clay; there may be one or two layers of karang, or the whole soil may carry tin, from bed-rock to grass-roots. The section presented in Fig. 3 of an open-cast mine near Seliben may serve as perhaps a typical deposit. The tin occurs as small black crystals, usually, but not always, water-worn, mixed with tourmaline, ilmenite, and other impurities, which will be referred to later. Another interesting and frequent variety is the occurrence of tin in heavy red ferruginous clays, which often carry values throughout their depth. One of the most striking instances of this class is the Tambun mine, 4 miles NW. of Ipoh, which, at the time of my visit to the district in 1903, was the richest mine in the valley, producing 350 tons of concentrates a month, assaying 68 per cent. of metallic tin. The average value has been calculated from the number of cubic yards washed in a month and the amount of concentrates obtained; but a sample taken by me from a number of car-loads gave a higher result,—76.8 lb. per cu. yd. Fig. 4 shows a section of the deposit.

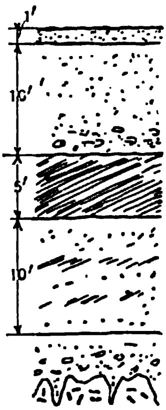

FIG. 3.—SECTION OF OPEN-CAST MINE NEAR SELIBEN.

The deposit was situated at the top of a small rise and appeared to be completely isolated, boring operations which had been energetically carried on in the vicinity failing to prove an extension of the deposit.

The red and black karang carried a considerable quantity of iron oxide and some manganese: the tin often occurred in the boulders and lumps of ironstone mentioned above; indeed, the mine had erected a special plant to deal with them. The cassiterite was much less water-worn than in many of the alluvial deposits (good crystals being by no means uncommon), and ranged in size from lumps as large as a man's fist down to the finest sand. The granite contact is 2 miles from the mine.

Another well known and almost equally rich mine is at Tronoh, 9 miles SW. of Batu Gajah. This mine is situated at the bottom of a small hill, and is supposed to be about 200 ft. deep; when I visited the mine, June, 1903, bed-rock had not been reached. The overburden of about 50 ft. consists of red and yellow sand and clay, the karang being a heavy blue clay,

in which appear white water-worn pebbles of quartz; the latter are supposed to be characteristic of the places where the richest tin occurs.

The bed-rock, although not exposed, is almost certainly limestone, which occurs in the vicinity and also in shafts that have been sunk close to the deposit. The cassiterite is considerably more water-worn than at Tambun, and is found as clean black crystals, without any admixture of iron oxide; the concentrates, however, contain a small amount of iron pyrites.

There are numerous other mines that might be described, notably those on the slopes of the mountains,—often on granite bed-rock, generally low in tin values and much mixed with tourmaline, ilmenite and granite decomposition-products. There is also a very interesting series of deposits in the hollows of the limestone-cliffs mentioned above; these deposits, often 500 ft. or more above the level of the valley, are invariably found in a red ferruginous clay, containing water-worn pebbles of iron oxide. The values are not often high, but the tin runs throughout the deposit, being, however, richer near bed-rock. These last-named deposits afford some measure of the enormous time that the present denudation of limestone and granite and the concentration of their heavier particles has been taking place, and awakes speculation as to the amount of concentration and reconcentration that has been going on since the cassiterite was first weathered out of the rock.

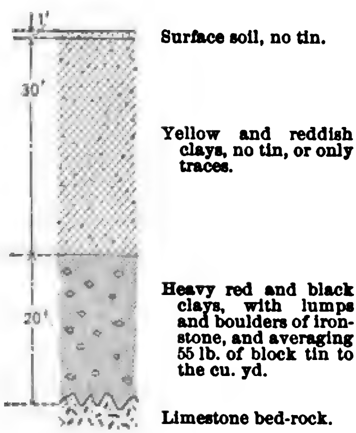

FIG. 4.—SECTION OF TAMBUN MINE.

The minerals met with in the wash include magnetite, tourmaline, ilmenite, iron pyrites, wolframite, garnet, zircon, spinel, corundum, and in one mine an interesting concentration of cerussite.

The tourmaline, ilmenite, zircon and garnet occur more abundantly near the granite contact, the tin in these mines being free and in black crystals; in the red clay-deposits these

minerals are rare, and generally entirely absent, the tin in the latter cases being found with iron oxide.

THE LODE DEPOSITS (in contradistinction to alluvial deposits):

(1) *Those in Granite.*—Most writers on the alluvial deposits of the Malay Peninsula state that the tin of the alluvium must have been derived from stockworks or lodes in the granite, yet can point to but very few instances. This failure to find the "root-deposits" may be ascribed to the thickness of the alluvial covering and to the denseness of the jungle; but surely such sweeping assertions as are sometimes made should be based on stronger evidence than hitherto has been adduced. The only lode in the granite, or indeed any tin-deposit in that rock, that I have seen in this district was one west of Lahat, at the bottom of the granite range and near the contact with the limestone. This lode was about 2 ft. wide with no well-defined walls, the lode-stuff consisting of an intimate mixture of gray cassiterite and iron pyrites with a little quartz; it appeared as though the minerals had replaced the original feldspar in the granite, and the deposition had taken place along a joint-plane in the rock.

(2) *Those in Limestone.*—There seems to be a general belief that the occurrence of cassiterite in limestone is, if not an impossibility, so rare that the discovery of profitable lodes in that rock is hardly worth discussion; but if limestone is in connection with intrusive stanniferous rocks there appears to be no sound reason against the occurrence of tin in it, just as plentifully as in slate rocks placed in a similar position.

In the Kinta valley there are at least three deposits of tin in limestone; probably more, but the difficulty of obtaining any reliable information as to deposits that have been abandoned and are supposed worked out, makes it often impossible to be sure whether a mine was alluvial or otherwise.

The three deposits actually seen by me were those of Chunkat Parit, Saiah, and a mine owned by the French Mining Co. near Lahat.

In Chunkat Parit, one mile west of Ipoh, at the time of my visit, the lower workings were under water, and I had to be content with a look at the outcrop, the dump, and specimens. The outcrop could not be traced for any great distance, and the

lode did not show signs of well-defined walls, but appeared to follow roughly a bedding-plane in the limestone, striking N–S., and apparently rapidly thinning out at each end. The lode-stuff was a mixture of brown fine-grained cassiterite, erubescite, and chalcopyrite, with a limestone gangue. The country-rock was the usual highly crystalline limestone, the deposit being about two miles distant from the granite contact.

Saiah, close to Seputeh, SW. of Batu Gajah, is an open-cast mine worked by a Chinaman. Unfortunately, here, too, I was unable to make a close examination, not being allowed to enter the workings; but it appeared that the mine had been originally worked for fairly rich alluvium, and when this had been followed down into one of the cracks of the limestone, a lode deposit was discovered. The lode-stuff consisted of cassiterite, arsenical pyrites, iron pyrites and quartz, some of which had been deposited in well-developed crystals. The country-rock was limestone, the deposit, as far as could be seen, following the general strike of that rock. It was two miles from the nearest granite outcrop known to me.

The third deposit, situated a little east of Lahat, and owned by the French Mining Co., was by far the most interesting and most instructive.

The discovery had only recently been made, when I was kindly given the opportunity of examining it. The lode had been stripped of its alluvial covering for 50 ft. along the strike; whether the alluvium had been rich in tin, and whether this fact had led to the discovery, I am unable to say. The lode was 8 ft. wide with a NE–SW. strike, and dipped at a steep angle to the west. It was composed of an intimate mixture of red iron oxide and cassiterite with a little iron and copper pyrites, the gangue being calcite and limestone, while there were some very large and beautiful crystals of calcite on the hanging-wall. The walls were fairly well defined, much more so than in either of the previous deposits described. The granite contact was a mile to the west of the mine.

I much regret that I have no details as to the subsequent developments; the company were starting to prove the existence or otherwise of the lode in depth by a core-drill.

ORIGIN OF THE DEPOSITS.

The origin of the deposits, as already mentioned in this paper, seems to be generally accepted that the alluvial tin has been derived from original deposits in the granite, and as proof thereof there are cited the few lodes that have been discovered, the analogy to the Erzgebirge and other tin-fields, and sometimes also the fact of the constituents of the granite being found with the tin in the karang,—this latter a most remarkable statement. One might just as well argue that, because one of the mines mentioned above contained cerussite, obviously eroded from the limestone, therefore the minerals mixed with the cerussite, such as quartz, tourmaline, feldspar, cassiterite and even granite pebbles themselves had been derived from the limestone.

The absence of certain minerals, however, may sometimes be of use in determining the origin of the alluvium.

At the same time, although I think that in a few cases it can be proved otherwise, it is possible and even probable that a great many, perhaps a great majority, of the tin-deposits have been derived from the granite. There is the proof of the tin-alluvium found on the slopes of the hills and on granite bedrock, in some cases far away from and above the limestone, which must have been derived from the granite itself; it is also noticeable that the sides of the valley are richer than the center, in which place mines are conspicuous by their absence.

But in the case of such a deposit as the Tambun mine, 2 miles from the granite, the karang rich in iron oxides and manganese, the cassiterite only slightly water-worn, the occurrence of the latter in ironstone in large blocks, the isolated character of the deposit, and the failure to trace any "lead," would naturally suggest its local origin; and when to this is added the actual occurrence of tin in limestone, especially in the case of such a deposit as that described at Lahat, which, with its intimate association of iron oxide and tin, would tend to produce just such an alluvium as is seen in the Tambun mine, it is for me an impossibility to go back to granite for its origin. It is perhaps superfluous to add that, because a deposit such as the one referred to has been derived from a lode in the limestone, it does not necessarily follow that the root-deposit can be

discovered, since the alluvium was very probably the result of the disintegration of rich pockets, the ores of which perhaps arrived through fissures, which at the present plane of erosion have no marked distinguishing features.

Mr. Scrivenor, in his paper already referred to,[3] writes:—

"So far, I have seen nothing in the ironstone which cannot be accounted for by the deposition and subsequent oxidation of iron carbonate conveyed in solution by percolating water. That the water should find its way along the bedding-planes is not surprising, seeing the high angle at which these planes are placed."

Again he says:—

"After the deposition of the alluvium percolating water carrying iron carbonate in solution caused the formation of the cemented karang and the laterite."

I do not know whether Mr. Scrivenor would call the Tambun karang laterite or not, but it seems to me a little difficult to imagine ascending solutions of iron carbonate circulating through the upper part of the limestone without precipitation, and then forcing their way through a most impervious stratum of alluvial clay. Surely, in alluvium, if anywhere, we must find rather descending oxidizing solutions, and I should be much more inclined to attribute the laterite and cement-beds to the solution of iron oxides from the granite and limestone by organic acids derived from decaying vegetation, and subsequent precipitation of the iron thus carried. Nowhere in the world would such organic acids have a better opportunity of forming than in the moist climate and dense vegetation of the Malay States. The bleaching of the shales to which Mr. Scrivenor alludes may perhaps be accounted for by the acids found in this way.

The Tronoh mine appears to be as isolated as that of Tambun, but there do not seem to be such definite proofs of its derivation from limestone as in the latter; on the other hand, definite proofs of its derivation from granite appear to be equally lacking.

There are many other mines, especially those which are some distance from the granite contact, the origins of which seem referable rather to deposits in the limestone than to those in the granite; that is, given the possibility of the occurrence of

[3] *A Preliminary Report on the Geology of the Neighborhood of Taiping.* (Published as *Supplement to the "Perak Government Gazette,"* Jan. 15, 1904.)

tin in the limestone, which is a fact beyond dispute. With regard to the concentration of the cassiterite, especially in explanation of the occurrence of two or more layers of karang, I think that Posepny's theory[8] is excellently illustrated, namely, that of the sinking of the heavier constituents through a loose mass with the aid of water until the particles reach bed-rock or a relatively impervious stratum.

In every case that I noted, where there were two distinct beds of karang, the top bed was invariably lying on clay; sometimes the clay itself was a tin-bearer, as though the heavy particles had endeavored to work their way through the close-packed bed, but had found the process so difficult that they had become concentrated there.

As regards the origin of the "root-deposits" themselves, there seems for the granite no reason to depart from the usually accepted theory of tin-deposits, namely, that they are formed by the after-actions of the eruptive rock; but in the limestone it would seem more in accordance with the facts to suppose that the lodes were formed by ascending waters, doubtless closely connected with the pneumatolytic after-actions.

In conclusion, I desire to remark on the extraordinary indifference which is, or at any rate until lately had been, displayed by the Government of the Federated Malay States in matters geological, and on the extreme reticence which characterizes the Department of Mines, even as to the small amount of information which they have collected.

It is not too much to say that at present the country is absolutely dependent, for its progress and for its commercial and financial existence, on the tin industry. The tax on tin pays for the roads, the railways, the many fine government buildings, and the salaries of those that work in them; and yet it is only quite recently that the Government has appointed a State Geologist. In a mining country in which mines are so quickly discovered, worked out and abandoned, as in the Kinta valley, it seems of enormous importance that careful records of each mine should be kept, and such points as the character of the overburden, karang, and bed-rock, the accompanying minerals, the approximate richness of the karang, etc., etc., should be

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[8] *Genesis of Ore Deposits*, p. 153.

noted, correlated with others, and published, together with borings or any other exploratory work which may be undertaken by the Government. That one man, however able, can collect these data as well as fulfill his more strictly geological work, is of course impossible; but the mining inspectors, many of whom are technically trained men, might certainly make use of their exceptional opportunities in this direction, and aim at being something more than "Guardians of the Water," as the Malays and Chinese now call them. In such ways we might be able to learn more of these unique and most interesting deposits, and not only speculate as to their origin, but be able to point to paying lodes as evidence of our theories.

To quote Posepny's famous work again (p. 3):

"Mining, indeed, constantly furnishes fresh evidences in new openings, but it destroys the old at the same time; and if these are not preserved for science before it is too late, they are lost forever. The whole mining industry is in its nature transitory, but the nation, which intrusts to the miner, upon certain conditions, the extraction of its mineral wealth has a right to demand that the knowledge thus gained at the cost of a part of the national resources shall not be lost to science."

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Clays of Texas.*

BY HEINRICH RIES,† ITHACA, N. Y.

(London Meeting, July, 1906.)

CONTENTS.

* Published by permission of the director of the University of Texas Mineral Survey. The chemical analyses are by O. H. Palm and S. H. Worrell, of the University of Texas.

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I. Introduction.

The facts presented in this paper, based chiefly on a reconnaissance made, during the summer of 1903, by myself and my assistant, Mr. R. C. Brooks, cover practically all that portion of Texas lying east of the 99th meridian. The work was undertaken for the University of Texas Mineral Survey, and was to have been extended over the entire State, but the sudden termination of the survey prevented even the official publication of the results already obtained.

Most of the mineral resources of Texas were fully treated by the First Geological Survey, but the clay-industry was at that time little developed, so that only a few scattered notes concerning it are to be found in the Survey reports. The extensive exploitation of the clay-deposits, however, has emphasized their commercial importance, and has also made accessible many facts of exceptional interest concerning their geologic conditions.

The erection of new plants for the utilization of clay-products is usually preceded by more or less prospecting, which, by reason of the scarcity of outcrops, and the geologic and topographic conditions of eastern and southeastern Texas, is often slow and difficult work. This is especially true in the Tertiary and Pleistocene areas, where the structural conditions much resemble those of the Atlantic coastal plain, the deposits being mostly lenticular in form, and surrounded by beds of sand.

II. General Geology of the Clay-Deposits.

The accompanying sketch-map, Fig. 1, shows the location of nearly all the deposits examined, their relation to the geology of the State, and the type of clay found in each. The geology is based on the published work of Hill, Cummins, Taff, Adams, Hayes and Kennedy, but the boundaries have unfortunately not been determined over the entire region covered by the map, and, in many areas, are only approximate. It will be seen that the clay-deposits range from Carboniferous to Pleistocene in age, the older deposits being found in the northwestern part of the area, while those of Cretaceous and Tertiary age lie to the east, southeast and south. The Pleistocene clays are found in part in a belt along the coast, and in part along many of the larger rivers, where they often underlie extensive terraces.

Table I. gives the geological succession of the clay-bearing formations of eastern Texas.

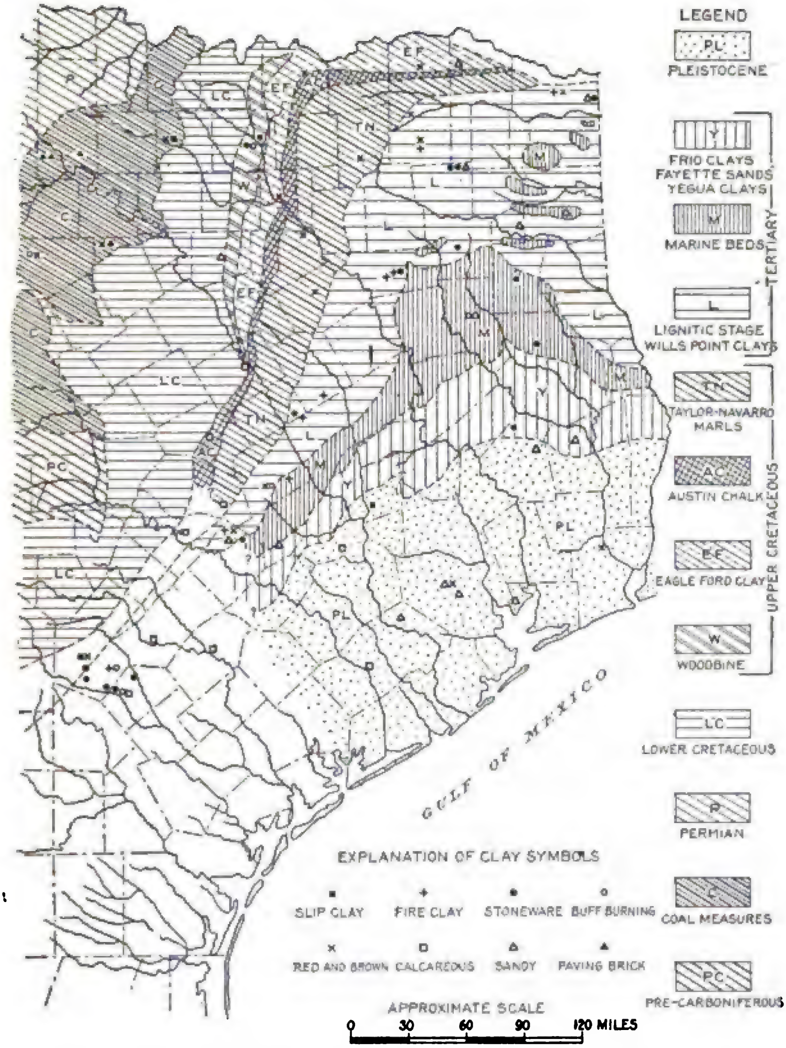

FIG. 1.—SKETCH MAP OF THE GEOLOGY OF NORTHEASTERN TEXAS, SHOWING THE LOCATION OF CLAY-DEPOSITS.

III. CARBONIFEROUS CLAYS.

The Carboniferous rocks of northern Texas outcrop in a broad belt about 250 miles long and 45 miles in average width,[1]

[1] 22*d* *Annual Report*, *U. S. Geological Survey*, pt. iii., p. 402 (1902); also 1*st* *Annual Report* (1889), p. 201, and 2*d* *Annual Report* (1890), *Texas Geological Survey*.

TABLE I.—*Geologic Formations of Eastern Texas.*

Age.	Period.	Formation.	Thickness.	Character of Beds.
	Pleistocene.	Beaumont clays	Feet. 25 to 400	Brown clays and sands with shells and lime pebbles.
		Columbia sands	50 to 200	Various colored sands above, sands and clays below.
Tertiary.	Neocene.	Lafayette, etc	880 to 1,355	Sands and clays, with some limestones and sandstones.
	Eocene.	Frio clays	160	Thinly laminated clays of various colors; many limestone concretions.
		Fayette clays	400	Gray sands, sandstones and clays.
		Yegua clays	1,000	Blue gypseous clays and gray sands with lignite-beds.
		Marine beds	650	Impure clays and sands, often glauconitic.
		Lignitic clays	1,060	Sands of various colors interbedded with clays, and lignite-beds.
		Will's Point clays	260	Yellowish-brown sands, laminated clays, and limestones.
Cretaceous.	Upper Cretaceous.	Navarro marls	800	Calcareous clays, often sandy or glauconitic.
		Taylor marls	1,000	Calcareous clays.
		Austin chalk	410 to 625	Limestones, sometimes chalky in character.
		Eagle Ford	600 or less.	Bituminous clay-shale, often gypsiferous and containing some limestone-beds.
		Woodbine	600 or less.	Ferruginous sandstones and clays, the latter of economic value locally.
	Lower Cretaceous.	(Contains no known clays of value, hence not differentiated.)		Limestones and marly clays.
Carboniferous.	Middle Carboniferous.	Albany	0 to 1,180	Limestone and shale with thin coal-strata.
		Cisco	800	Chiefly shale; scattered beds of limestone and sandstone as well as coal.
		Canyon	800 to 980	Limestones and shales with occasional sandstones and conglomerate.
		Strawn	950 to 3,700	Sandstones and shales.
		Millsap	1,000	Blue and black shales with occasional limestones and sandstones; some coal.

extending from the south side of the Colorado River valley, between Lampasas and Concho counties, northward as far as the Red river in Montague county. They present a succession

of shales and sandstones, with occasional beds of limestone and coal, having a slight monoclinal dip of a few feet per mile to the west and northwest, and divisible, according to Cummins, into the five groups indicated in Table I.

Scattered through this series are a number of beds of shale of excellent quality, some of which are associated with coal-seams, and could be mined in connection with them, while others outcrop on the surface, where they are easily reached and can be economically worked. No detailed survey has been made of these shale-beds; but such as have been examined are very promising. At only three localities, viz., Thurber, Millsap and Weatherford, are they now utilized for the manufacture of clay-products; but other Carboniferous shale-beds are known at Graham, Bridgeport and Cisco. None of these are yet known to be of refractory character, but they are adapted to the manufacture of paving-brick, pressed brick and pottery, and for glazing-purposes.

The uniformity of the Carboniferous shale-beds is much greater than that of the Tertiary clays, and they extend over greater areas. Although as yet but little developed, these shales will probably form the basis of an important industry when their value becomes known, since they are easily accessible from the markets of Fort Worth, Dallas and many other large towns.

IV. Cretaceous Clays.

1. *Lower Cretaceous.*

The formations of this age occupy an area east and south of the Carboniferous beds. They are not utilized, nor do the stratigraphic details thus far published indicate any promising beds of clay, the formation being usually very sandy.

2. *Upper Cretaceous.*

This division carries a number of important clay-deposits, some of which are the most extensive, but unfortunately not the most valuable, in the State. The persistence in extent and the greater thickness of these deposits, as compared with the Tertiary deposits, indicate the existence of more uniform conditions during their sedimentation.

These rocks extend across Texas in a broad belt from the

Red river, north of Sherman, down to Eagle Pass, which lies in about the middle of the band; Fort Worth is on the western edge and Austin towards the southeastern border. This same series of beds also forms a belt along the Red river, the width of which narrows until it passes out of the State in the northeast corner. Since the dip is to the southeast, the older beds are found along the western edge of the belt, and the higher or younger ones on the east, where they pass below the Tertiary strata. The following members are recognized:—

(a) *Woodbine Formation.*—This is regarded as the equivalent of the Dakota, and consists of a series of sandstones, clays and clayey sands, which often carry leaf-impressions and lignite, thereby showing their shallow-water origin. To the north it is 600 ft. thick, but thins out towards the south. While the clay-beds are usually sandy or even bituminous, they become locally pure enough, as at Denton, to be utilized for the manufacture of clay-products, although even here the beds are rarely of great extent and usually interrupted by sandy layers. The individual deposits, however, are of sufficient size to supply a fair-sized plant. In their chemical composition the clays closely resemble the stoneware clays of the lignitic stage of the Tertiary.

(b) *Eagle Ford Formation.*—This is one of the most extensive and thickest of the clay-bearing formations in the entire State of Texas, and consists of a series of bituminous clays which are often of more or less shaly character, with occasional thin limestone-beds or nodular septaria. The formation occupies a north-south belt, extending from a point southwest of Austin to the Red river, and then swings eastward from Bells, Grayson connty, to the eastern part of Lamar county.

In the counties of Dallas, Collin and Grayson, where the formation has its greatest development, the following section has been worked out by Hill.[2]

Beginning at the bottom there are thinly laminated deep-blue or black clays, with occasional sand-laminæ, which pass upward into less siliceous clays, containing irregular bands of thin calcareous matter and ferruginous clay nodules, as well as many lumps and flakes of selenite. The central part of the forma-

[2] 21*st Annual Report, U. S. Geological Survey,* pt. vii., p. 324 (1901).

tion carries layers of arenaceous sandstone, and is then succeeded by the upper part of blue-black clays, carrying many spherical septaria.

While the Eagle Ford clays are of great thickness and well located for working, they contain nearly all the undesirable elements that a clay may contain, namely, concretions, limestone-pebbles, gypsum-lumps, pyrite, and much organic matter. Moreover, their bituminous character and their extreme toughness, cause great trouble in manipulation, and practically force the clay-worker to mold it by the dry-press process, other methods yielding a brick too dense to permit the carbon in the clay to burn off. By reason of its proximity to several large cities, the Eagle Ford clay is extensively used for brick-making, being worked at Paris, Sherman, Dallas and Waco. Fig. 2 shows a characteristic exposure of it near Dallas.

(c) *Austin Chalk.*—This overlies the Eagle Ford formation, and is in places an earthy limestone which carries no deposits of clay of economic value. Its intimate association with the Eagle Ford shale, however, makes it of value for admixture with the latter for the manufacture of Portland cement.

(d) *Taylor Marls.*—These form a somewhat broad belt underlying the "Black Waxy" region and extending parallel with the Eagle Ford shale and Austin chalk in both their N.–S. and E.–W. course. Their general character is that of marly clays, and in their physical and chemical properties they bear a close resemblance to Eagle Ford beds. They are not sharply separable from the next member. Fig. 3 is a pit in Taylor marls at Ferris, Texas.

(e) *Navarro Marls.*—These rest on the Taylor marls and represent the highest division of the Cretaceous in eastern Texas. While distinguishable with some difficulty from the Taylor marls, they are usually more sandy, and contain some glauconitic material; they also yield a black soil. To the eastward they pass under the loose beds of Tertiary material. On the geologic maps which have been published no attempt is made to separate the Taylor and Navarro marls, the two forming one belt extending from northwestern Bowie county through Red River, Delta, Hunt and Collins counties, where they turn southward and form a belt about 35 miles wide between the Austin chalk and the western border of the territory. The clays of these two

marl-formations are, on the whole, more extensively utilized than the Eagle Ford shales, and at times possess to some extent the same undesirable properties. Deposits belonging, probably, to the Navarro marls are worked at Taylor and Ferris.

3. *Comparison of Eagle Ford Clays and Taylor-Navarro Marls.*

Table II. gives the minimum, maximum and average percentages of the ingredients of these two types of clay, those of the former being the average of eight analyses, and those of the latter, of six.

TABLE II.—*Comparative Analyses of Eagle Ford Clays and Taylor-Navarro Marls, Texas.*

	Eagle Ford Clays.			Taylor-Navarro Marls.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
SiO_2..................	67.00	34.60	55.74	79.00	47.92	55.78
Al_2O_3..................	23.80	15.02	20.00	21.27	11.38	16.34
Fe_2O_3..................	6.48	1.87	4.17	8.37	2.44	4.43
CaO..................	21.48	tr.	4.07	12.67	0.50	7.91
MgO..................	2.09	0.15	1.35	2.14	0.20	1.15
K_2O..................	1.65	tr.	0.73	1.38	....	0.65
Na_2O..................	2.00	0.05	1.07	1.60	tr.	0.79
TiO_2..................	2.10	0.96	1.52	1.22	0.70	0.90
H_2O..................	7.06	5.20	6.06	6.90	3.80	4.94
CO_2..................	15.60	tr.	2.79	9.50	....	5.25
Organic matter....	3.00	....	1.55	1.4	1.34	1.38
SO_3..................	3.37	....	0.79	2.00	1.12	1.52

The averages in Table II. show a close agreement, the main difference being the higher alumina-content of the Eagle Ford and the higher lime-average of the Taylor-Navarro beds (although the former showed a higher maximum percentage of lime). The difference in their composition is, however, so small that it does not make itself felt in the utilization of the clay. Both are comparatively high in organic matter—too high, in fact, to permit their being easily burned; and both run high in SO_3, due chiefly to the presence of gypsum, and, to a small extent, of pyrite. It is possible that the decomposition of the latter has been in part responsible for the formation of the gypsum, through the reaction of sulphuric acid on the calcium carbonate in the clays.

V. Tertiary Clays.

The Tertiary deposits of Texas are of both Eocene and Neocene age. The former include beds of great economic value, while the latter are usually very sandy, and carry but few argillaceous beds of good quality. While the Eocene clays are of great economic importance, the lenticular form of the deposits and the enveloping bodies of sand with which they are frequently associated render their discovery more or less difficult. The lack of outcrops and the heavy mantle of vegetation are also serious obstacles to rapid prospecting.

It appears, however, from the wide distribution of the deposits already examined, as shown in Fig. 1, that, at least in certain belts of territory mentioned below, clays may be sought with excellent chances of success. This being the case, the delineation of the boundaries of the several subdivisions of the Tertiary becomes a matter of considerable importance. Unfortunately, no published map exists, showing the boundaries of the Tertiary formation southwest of Bastrop and Robertson counties. The Tertiary beds of that portion of Texas lying east of the 99th meridian consist largely of unconsolidated materials, from coarse gravels to very fine clays, but contain also occasional beds of sandstone, limestone and lignite. The several subdivisions of the Tertiary are given in Table I., and the characters of the Eocene ones are briefly as follows:—

(a) *Will's Point Clays.*—These beds, the basal Eocene deposits in Texas, consist usually of a stiff, laminated, yellow or bluish-green clay, with interbedded deposits of sand, as well as some calcareous beds. The clays themselves, besides being somewhat calcareous, are quite sandy, and often contain crystals of gypsum. These features collectively tend to decrease their value for the manufacturer.

(b) *Lignitic Clays.*—This formation, overlying the Will's Point group, outcrops through a broad irregular area, as shown on the sketch-map, Fig. 1. It comprises a series of sands and clay-beds, and often (especially near the base) carries beds of lignite, from a few inches up to 12 ft. in thickness, and, at many localities, interstratified with beds of shale and clay—the shales being sometimes semi-refractory, while the clays are non-refractory, but possess excellent plasticity. A third type,

worked at New Boston and Sulphur Springs, is a red-burning, tough, shaly clay, physically not unlike some of the Taylor-Navarro marls, but containing much less lime. A fourth and more widely distributed type is represented by lenticular deposits of grayish, highly plastic, refractory or semi-refractory clay, occurring throughout the entire lignitic belt, and already opened up in Bexar, Wilson, Limestone, Bastrop, Falls, Henderson, Smith, Wood and Bowie counties.

Table III. gives representative analyses of the clays of this group.

TABLE III.—*Analyses of Tertiary Clays, Texas.*

	I. Semi-Refractory Clays, Average of Two Analyses.	II. Red-Burning Clays, Overlying the Lignite.	III. Stoneware and Fire-Clays.
	Per Cent.	Per Cent.	Per Cent.
SiO_2,	69.33	72.9	70.65
Al_2O_3,	19.38	14.7	18.14
Fe_2O_3,	1.06	4.5	0.82
CaO,	0.86	0.6	0.339
MgO,	0.86	0.3	0.628
K_2O,	tr.	1.5	0.41
Na_2O,	0.08	0.7	0.55
TiO_2,	1.40	1.0	1.147
H_2O,	5.49	4.2	6.187

The highly siliceous character of all three classes cannot fail of notice, while II. differs from I. and III. chiefly in its percentage of ferric oxide, the excess of which seems to replace alumina. The analyses give no indication of the physical differences. All three, it will be noticed, show appreciable amounts of titanic acid. The wide distribution of these clays within the lignitic area is shown on the map, Fig. 1.

Figs. 4 and 5 show deposits of these lignitic clays at Saspamco and Athens. Since the heavier beds of lignite occur towards the base of the formation, the shales associated with them are to be sought next to the northwestern and northern borders of the area. Not all of the shales associated with the lignites are of good quality, some being too ferruginous and others too carbonaceous.

(c) *Marine Beds or Lower Claiborne Stage.*—This formation is generally sandy or glauconitic, but carries, here and there, deposits of clay possessing some economic value, and, indeed, resembling those of the Lignitic group. The formation outcrops

in a broad hook-shaped area, mostly east and south of that underlain by the lignitic deposits, but with some outliers in the latter, in Cass, Harrison and Gregg counties, as shown in the map, Fig. 1. Clays, presumably of the Marine stage, are worked at Rusk, Nacogdoches and Henderson. Those at Henderson, however, are so near the boundary of the Lignitic that they may possibly belong to it. If similar deposits should be hereafter found at intermediate points, the Marine beds will closely approximate in importance those of the Lignitic formation.

(d) *Yegua Clays, Fayette Clays and Frio Clays.*—These formations complete the deposits of Eocene age. So far as now known, they do not contain clay-beds of value.

VI. Pleistocene Clays.

Along the coast, the Pleistocene deposit forms a broad belt, extending from the southeastern border of the Tertiary to the Gulf of Mexico. The deposits are of several types, including beds of clay, sand and gravel, and, while attempts have been made to differentiate them, the subdivisions are mostly of little value to the clay-worker. Of the several groups recognized, perhaps the most important is that of the Beaumont clays (Figs. 6 and 7), which are tough, plastic, brown, blue and yellow clays, carrying irregularly distributed nodules of limestone. They underlie a broken belt extending from Calhoun to Jefferson county, and are worked for brick-making around Beaumont and Houston. At Houston, especially, the irregular distribution of the limestone nodules is very marked, the brick of one pit being full of them, while that of another may be quite free from them, and hence of much better quality. The beds are sometimes of very irregular thickness, filling depressions in a more sandy clay.

The other Pleistocene formations, underlying the broad belt bordering the Gulf, and not differentiated on the map, Fig. 1, contain scattered deposits of clay, mostly very siliceous, which are used, here and there, in the manufacture of common brick of poor quality, but have no other commercial value.

In addition to these, I should mention also the river-silts underlying the terraces along many of the larger rivers (Figs. 7 and 8), such as the Rio Grande, Colorado, Brazos, etc. These

range from silty clays, through silts to clayey sands, and are nearly always highly calcareous, the calcium-carbonate being present as concretions, lumps, shells, or in a finely-divided condition, and forming at times more than 50 per cent. of the material, without apparently diminishing its plasticity. They are especially well developed at Austin and Laredo.

VII. Classification of Clays.

The clays of the area under discussion have been divided into four classes, according, partly, to their physical and chemical characters, and partly to their practical applications. The names are those usually adopted in similar classifications; but in order to prevent any misinterpretation, the characters of each class will be stated. The grouping adopted is as follows:—

1. Fire-clays.
2. Stoneware-clays.
3. Brick-clays.
   - (a) Buff-burning non-calcareous brick-clays.
   - (b) Red- and brown-burning brick-clays.
   - (c) Calcareous brick-clays.
   - (d) Sandy brick-clays.
   - (e) Paving-brick clays.
4. Slip-clays.

1. *Fire-Clays.*

The fire-clays include all those, the fusing-point of which is not below 1,670° C. (3,038° F., or the equivalent of Cone 27 of the Seger series). They are always low in fluxing-impurities, such as iron oxides, lime, magnesia and alkalies, contain a medium percentage of silica, and often a high percentage of alumina.

Their refractoriness increases as they approach kaolinite in composition; and it is not uncommon to divide them into fire-clays and semi-fire-clays, or into grades No. 1 and No. 2, the latter grade being frequently used for stoneware manufacture.

2. *Stoneware-Clays.*

Usually at least semi-refractory; the majority fusing not lower than 1,670° C. (3,038° F., or Cone 27 of the Seger series). They possess the excellent plasticity necessary to permit molding into jugs, pots, etc., and burn to a practically nonabsorbent body at the temperatures usually reached in stoneware-kilns.

FIG. 2.—BANK OF EAGLE FORD CLAY, WEST DALLAS, TEX. (p. 773).

FIG. 3.—PIT IN TAYLOR MARLS, FERRIS, TEX. (pp. 773, 794).

FIG. 4.—LIGNITIC CLAY USED FOR SEWER-PIPE, SASPAMCO, TEX. (pp. 776, 788).

FIG. 5.—LIGNITIC CLAY, ATHENS, TEX. (p. 776).

Fig. 6.—Pit in Beaumont Clay, Covered with a Layer of Sand from 1 to 2 Ft. Thick, Beaumont, Tex. (p. 777).

Fig. 7.—Pit in Beaumont Clay. The Sides are Light-Colored Sandy Clay of Columbian (?) Age, Houston, Tex. (p. 777).

FIG. 8.—CALCEROUS TERRACE DEPOSIT WORKED FOR COMMON BRICK CLAY, LAREDO, TEX. (p. 777).

FIG. 9.—SILTY CLAY UNDERLYING TERRACE ALONG COLORADO RIVER, AUSTIN, TEX. (p. 798).

3. *Brick-Clays.*

Used for the manufacture of common, pressed and paving-brick. Since these clays represent a wide range of material, which for each class shows more or less definite properties, the group has been subdivided as follows:

(a) *Buff-Burning, Non-Calcareous Brick-Clays.*—These are semi-refractory clays, which, by reason of their low percentage of iron oxide, burn to a buff color. They are frequently quite siliceous, and aside from their color-burning qualities and refractoriness, vary considerably. While their main use is for ornamental brick, they are also employed for making terra-cotta and low-grade fire-brick.

(b) *Red- and Brown-Burning Brick-Clays.*—Commonly of low refractoriness, due to a high content of fluxing-impurities, and burning red or brown, because of a high percentage of iron oxide. They all possess good plasticity, and burn hard and at least fairly dense, at a comparatively low heat. While the main application of these clays is for common-brick manufacture, they are also used for pressed brick.

(c) *Calcareous Brick-Clays.*—Those brick-clays which contain a high percentage of calcium carbonate, and in which the lime-content is commonly at least three times as great as that of the iron oxide percentage, on which account they burn buff, but differ from the sub-class (a) in the lower fusibility. These clays range from very plastic to very siliceous materials, yield a rather porous product, and, in the main, are adapted to little else than common brick.

(d) *Sandy Brick-Clays.*—Certain occurrences of red-burning clays are so highly siliceous as to warrant placing them in a group by themselves. Owing to high silica-content these clays are of low plasticity, and burn to a very porous product. Though frequently containing a high percentage of fluxes, the fusion-point is raised by the high silica-content. These clays have little value except for the commonest grades of brick.

(e) *Paving-Brick Clays.*—Certain plastic, fine-grained clays, of comparatively low fusibility, in which the fluxing and refractory elements are so balanced that the clays burn to a non-absorbent body, at comparatively low temperature, and attain this condition some time before they become viscous. These clays are not infrequently of shaly character.

4. *Slip-Clays.*

Clays containing so high a percentage of fluxing-impurities as to melt to a glass at the temperature at which stoneware is burned, and therefore used as natural glazes. Fineness of grain and proper chemical composition are the main factors of value in this group.

VIII. Physical and Chemical Tests of the Clays.

The economical value of a clay is most clearly determined by means of physical tests and chemical analyses, the former being the more important. In the physical tests it is necessary to determine the shrinkage in the air, as indicative of the degree of freedom from cracking in drying; the tensile strength, as showing the bonding-power; the fire-shrinkage at the temperatures at which each class of clay is likely to be burned; the absorption, to test the density to which the clay will burn; and the fusion-point. The chemical analysis gives valuable clues regarding the color-burning qualities, refractoriness, sandiness, etc. In testing the Texas clays, each sample was burned at six different temperatures; but in this paper only those results have been tabulated which were obtained at the two temperatures usually employed in burning clay in practice.

1. *Fire-Clays.*

The Texas clays which are used in the manufacture of fire-brick are refractory or, at least, semi-refractory. With the exception of a few occurrences in the Woodbine formation about Denton, these clays are confined to the Tertiary age. The deposits I examined were further restricted to the areas mapped in Fig. 1 as Lignitic and Marine—chiefly to the former. The most southerly deposit is at Adkins, Bexar county. The next occurrence northward is at Elgin, Bastrop county; and there are others in Bremond, Henderson, New Boston and Bowie counties, and two near Sulphur Springs in Hopkins county.

At none of these points are the beds continuously traceable for any great distance; and the frequent association with sands and sandy clays indicates that the conditions over that region during their deposition must have been changeable, and

that these beds are probably of irregular or somewhat lenticular form. This, however, has not prevented the occasional accumulation of bodies of considerable thickness.

One of the best sections seen was in the pit of the Athens Fire Brick Co. at Athens, where the beds dip about 5° SE. It shows, from the surface down, the following series: sand, 2 ft.; brick- and tile-clay, 8 ft.; and fire-clay, 15 ft., with sand below.

According to the Texas Survey[3] there are in this region at least five beds of fire-clay, from 2 to 12 ft. thick. A number of scattered openings have been made in them. To the northeast, in Hopkins county, the clays have been again opened up 6 miles southeast of Sulphur Springs, where the section is: mottled clay, 3 ft.; fire-clay, 12 ft.; and yellowish sandy clay, 2 ft., with sand below. This deposit has been proved over an area of 80 acres. The clay is slightly more refractory than that at Athens.

The deposit 6 miles south of New Boston agrees very closely in composition with that near Sulphur Springs.

Table IV. shows the results of physical tests and chemical analyses of the Texas fire-clays. Under the former head, the table gives the shrinkage and the absorption of the clay at the temperature of Seger cone No. 9 (1,310° C.), which is about the lowest heat at which the fire-bricks are likely to be burned. Its behavior at cone 1 (1,150° C.) is also given, to indicate its changes at a lower temperature.

The analyses in Table IV. show that all these clays, except one (from Milam Junction), are to be classed as siliceous, the silica-contents averaging 70.28 per cent. This somewhat impairs the refractoriness. The total fluxes range from 0.90 to 4.93 per cent., which is not excessive. The fusion-points range from cone 27 (1,670° C.) to cone 33 (1,790° C.), 9 of the 12 tested fusing above cone 30, and two as high as cone 33. Ten of the twelve can therefore be regarded as good fire-clays. The refractoriness does not stand in direct relation to chemical composition, since the factor of texture plays an important rôle in some of them, as in the clays from Athens and Bremond.

The physical tests show that most of the samples have at cone 9 (1,310° C.), a low or moderate shrinkage and moderate

[3] 1st *Annual Report*, p. 36 (1890), and 2d *Annual Report*, p. 186 (1891), *Texas Geological Survey*.

TABLE IV.—*Physical Tests and Chemical*

Locality.	Laboratory Number.	Physical Tests. Average Tensile Strength.	Air-Shrinkage.	Cone 1. 1150° C. Fire-Shrinkage.	Cone 1. 1150° C. Absorption.	Cone 9. 1310° C. Fire-Shrinkage.	Cone 9. 1310° C. Absorption.	Cone of Fusion Number.
		Lb. per Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
1.25 miles S. of Adkins, Bexar Co.	926	130.0	6.0	1.3	13.80	3.0	11.12	27
5.5 miles E. of Elgin, Bastrop Co.	957	186.0	9.0	4.7	6.36	5.7	0.225	30
5 5 miles E. of Elgin, Bostrop Co.	956	277.0	8.0	8.0	8.72	9.0	0.20	28
Milam Junction, Milam Co.	923	47.0	5.6	5.0	13.80	9.3	8.61	33
Bremond, Robertson Co.	952	43.5	4.0	0.3	13.13	.....	12.06	33
Headsville, Limestone Co.	954	64.0	4.0	0.6	15.97	3.0	11.92	30
Headsville, Limestone Co.	.....	46.0	3.3	.....	14.16	0.3	12.29	*a*
Athens, Henderson Co.	.....	155.0	8.3	1.6	13.13	4.3	6.83	30
Athens, Henderson Co.	852	114.0	6.6	0.6	12.87	0.3	11.58	27
Malakoff, Henderson Co.	849	106.0	6.1	3.4	14.68	7.0	8.30	*b*
Malakoff, Henderson Co.	850	160.0	6.3	1.7	13.15	4.0	0.22	*b*
Sulphur Springs, Hopkins Co.	870	68.6	4.3	2.4	13.43	4.3	8.34	31
New Boston, Bowie Co.	861	83.0	5.1	1.6	15.35	3.4	10.54	*a*

absorption. Some, however, such as those from Elgin, Malakoff and Athens, burn too dense if used alone, and have to be mixed with more porous material.

At the present time, the Texas fire-clays are but little used. Only those at Athens have been steadily worked. This is due partly to the small demand and partly to the fact that St. Louis fire-brick are shipped into the State at a very low price. With proper management, however, there seems to be an excellent chance for developing the Texas refractories, so that they can be used not only at home, but also, to some extent at least, by Mexican consumers.

2. *Stoneware-Clays.*

The stoneware-clays are found chiefly in the Lignitic Tertiary formations, although a few are known in the Carboniferous beds, as at Rock Creek, while those around Lloyd and

Properties of Fire-Clays, Texas.

Color After Burning.	Chemical Composition.										
	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	Total.	Total Fluxes.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Yellowish white.......	69.70	21.50	0.40	tr.	0.50	0.30	1.00	0.12	7.10	100.62	6.60
Buff..........................	65.60	22.50	1.20	0.70	tr.	tr.	1.70	1.10	7.70	100.50	3.60
Buff..........................	71.30	19.70	1.00	2.10	tr.	tr.	0.80	tr.	5.80	100.70	3.90
White........................	57.40	28.40	0.72	0.10	0.10	tr.	0.47	1.48	10.44	99.11	1.39
White........................	83.00	7.42	0.86	tr.	3.01	0.30	1.26	0.70	3.70	99.75	4.93
Light buff................	70.82	18.90	0.40	tr.	tr.	tr.	0.50	2.10	6.80	99.52	0.90
White........................	77.40	15.70	0.70	tr.	......	tr.	tr.	0.70	5.70	100.20	0.70
Light buff................	74.04	15.15	0.50	0.50	0.27	0.42	1.12	1.31	6.00	99.31	2.81
Buff..........................	67.29	15.29	1.59	0.83	tr.	tr.	0.12	1.18	4.75	100.55	2.04
Buff..........................	62.12	25.11	0.30	0.83	0.21	tr.	0.10	2.12	10.00	100.29	0.94
Buff..........................	61.88	20.47	0.21	0.50	0.30	0.15	0.33	1.40	6.68	99.92	1.49
Buff..........................	74.03	17.10	0.57	0.10	0.22	0.30	0.60	1.36	6.15	100.48	1.79
Buff..........................	78.68	17.01	0.50	0.08	1.20	tr.	0.15	1.57	6.00	100.19	2.93

Denton are of Cretaceous age. Omitting, for a moment, the Carboniferous and Cretaceous occurrences from consideration it will be seen that, beginning with the most southern locality described, viz., Strumberg, Bexar county, the stoneware-clays extend across the State in a general SW–NE. direction, the most northeasterly being at Texarkana, Bowie county (see map, Fig. 1), and all appear to be located within the areas of outcrop of the Lignitic and Marine divisions of the Eocene. There is some doubt in my mind whether those clays falling within the Marine areas as outlined on Adams's map,[4] really belong to this division, or are islands of the Lignitic, projecting through a thin layer of Marine beds. Similarly, some of those lying in the Lignitic area might belong to outliers of the Marine.

As a rule, the exposures are not large. One of the best is in

[4] *Bulletin*, No. 184, *U. S. Geological Survey* (1901).

the pit of the sewer-pipe works at Saspamco (Fig. 4), which shows: (1) sandy, laminated, iron-stained surface-clay, 4 ft.; (2) chocolate clay, 8 ft.; (3) yellow ferruginous clay, 1 ft.; and (4) tough, dense chocolate clay, 7 feet.

The beds dip gently to the southeast, and the deposit can be followed along the strike for at least 1,500 ft. The clays are interstratified with sands and sandstones.

The pit 3 miles SW. of Lavernia, shows: coarse yellow sand, 2 ft.; red sandy clay, 4 ft.; and dove-colored pottery-clay, 9 ft.

This, it will be seen, is quite different from the section given above. Additional sections would but serve to emphasize this irregularity. At most of the localities now worked the pits are small, and it is difficult to get any definite information regarding the extent of the individual beds without making a series of borings.

The constant feature of the deposits, however, is the character of the stoneware-clay, wherever found.

The only known occurrences of Cretaceous stoneware-clays are at Denton and Lloyd in Denton county, where the materials used represent, according to Hill,[5] a locally pure phase of the Kiamitia clays of the Woodbine, which is Upper Cretaceous. If this be so, there is little use in hunting for them north or south of these points; and the Tertiary formations must be the main source of supply in eastern Texas. The actual conditions at Denton are not very different from those in the Tertiary belt, the section at one Denton pottery showing: yellow mottled clay (rejected), from 4 to 6 ft.; and dove-colored pottery-clay, from 2 to 3 ft.; with sand below.

The pit at Lloyd shows from 4 to 7 ft. of pottery-clay; while, in the buff-burning brick-clay pit near Denton, the good clay has a total thickness of not less than 8 ft.

Table V. gives the physical properties and chemical composition of the Texas stoneware-clays, and shows them to present considerable uniformity in some respects and variation in others. They vary also in absorptive power for water (not given in the table), requiring, in mixing, from 18.7 to 34.1 per cent., with an average of 25.35 per cent. The majority show a low air-shrinkage; and, with few exceptions, the tensile

[5] 21st *Annual Report, U. S. Geological Survey*, pt. vii, p. 295 (1901).

strength is excellent. In almost every case, the fire-shrinkage increases gradually, while the absorption decreases with the temperature; so that at cone 5 many of them yield a body of good density. This is notably true of the clays from Strumberg, Nacogdoches, Cornersville and Winnsboro. The temperature reached in burning by the Texas potters is not known, but is probably below the fusion-point of cone 5 (1,230° C.).

At cone 9 there is obtained, in most cases, a considerable increase in the density of the ware, without increase in the fire-shrinkage. The temperature at which the clay-particles fuse sufficiently to become steel-hard varies from cone 03 to cone 9.

The average chemical composition of the Texas stoneware-clays is: SiO_2, 70.22; Al_2O_3, 18.14; Fe_2O_3, 0.99; CaO, 0.63; MgO, 1.28; Na_2O, 0.87; K_2O, 0.77; TiO_2, 1.15; H_2O, 6.80 per cent. They are therefore to be classed as siliceous clays, and their high silica-content is an influential factor in the depression of the fusion-point, which is still further lowered by the fluxing-constituents of the clay. The percentage of iron oxide is low, and hence the clays burn buff. The proportion of lime in all these clays is also small, except those which appear to belong to the Marine beds.

The fact that certain clays are here classed as stoneware-clays does not indicate that they can be used solely for this purpose. The term is rather to be regarded as an index of certain physical qualities characteristic of stoneware-clays. While the most important use is in the manufacture of stoneware, these clays are also employed for making buff brick, floor-tile, retorts, fire-brick,—in short, any kind of ware in which a fire-clay of plastic, more or less dense-burning quality, and good bonding-power is desired.

Since their value is never sufficiently high to permit their shipment to distant markets, these clays must be utilized near the deposits. The Texas stoneware-clays, therefore, await commercial development.

3. *Brick-Clays.*

The clays used for brick-manufacture in Texas can be classified on an economic basis as: (a) buff-burning, non-calcareous brick-clays of Carboniferous, Cretaceous or Tertiary age; (b) red and brown-burning clays, of Carboniferous to Pleistocene age, for common and pressed brick; (c) calcareous brick clays,

TABLE V.—*Physical Tests and Chemical*

Locality.	Geological Age.	Laboratory Number.	Physical Tests.							
			Air-Shrinkage.	Tensile Strength (Average).	Cone 1. (1150° C.)		Cone 5. (1230° C.)		Cone 9. (1310° C.)	
					Fire-Shrinkage.	Absorption.	Fire-Shrinkage.	Absorption.	Fire-Shrinkage.	Absorption.
			Per Cent.	Lb. per Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Denton, Denton Co.	Woodbine formation.	845	8.6	320	2.4	5.36	2.6	3.8	4.6	2.0
Lloyd, Denton Co.	Woodbine formation.	913	7.0	202	1.7	7.52	3.0	6.4	3.0	4.6
Strumberg, Bexar Co.	Lignitic Tertiary.	925	5.8	183	3.0	9.46	4.7	4.26	4.7	3.7
Elmendorf, Bexar Co.	Lignitic Tertiary.	808	6.8	245	3.4	8.69	4.3	6.35	4.4	2.29
Saspamco, Wilson Co.	Lignitic Tertiary.	807	10.2	257	3.3	6.57	5.7	2.83	9.4	0.82
Lavernia, Wilson Co.	Lignitic Tertiary.	948	7.3	204	3.3	7.8	4.6	3.6	10.66	2.1
McDade, Bastrop Co.	Lignitic Tertiary.	960	7.6	213	2.7	10.92	5.3	8.41	12.7	6.5
Denny, Falls Co.	Lignitic Tertiary.	953	6.3	217	4.0	9.29	5.0	5.53	6.6	1.38
Athens, Henderson Co.	Lignitic Tertiary.	853	7.0	90	4.0	12.47	6.0	8.71	10.4	1.52
Athens, Henderson Co.	Lignitic Tertiary.	854	6.8	143	4.0	13.76	6.4	11.21	6.5	7.45
Tyler, Smith Co.	Lignitic Tertiary.	928	6.6	224	0.7	11.81	1.7	9.16	2.0	6.51
Cornersville, Wood Co.	Lignitic Tertiary.	874	5.1	66	2.7	12.15	4.3	9.14	4.7	2.27
Cornersville, Wood Co.	Lignitic Tertiary.	874B	5.8	175	3.3	9.0	7.4	2.41	8.4	1.1
Winnsboro, Wood Co.	Lignitic Tertiary.	872	6.4	139	2.6	11.02	4.4	8.41	7.0	2.43
Winnsboro, Wood Co.	Lignitic Tertiary.	872B	7.2	163	7.0	6.08	8.9	0.21	4.6	......
Texarkana, Bowie Co.	Lignitic Tertiary.	858	6.6	140	2.0	13.14	4.3	8.32	6.7	2.4
Nacogdoches, Nacogdoches Co.	Lignitic Tertiary.	855	9.6	302	2.6	5.68	4.0	3.30	5.7	4.0
Henderson, Rusk Co.	Marine Tertiary.	929	6.0	89.7	4.0	12.22	5.0	9.32	6.3	6.34
Henderson, Rusk Co.	Marine Tertiary.	927	7.0	108	4.3	11.16	6.0	5.41	6.0	4.83

cream-burning, of Pleistocene age; (d) sandy, red-burning clays, mostly of Pleistocene age; and (e) paving-brick clays of Carboniferous age.

(a) *Buff-burning Non-Calcareous Clays.*—These are known to occur in the Cretaceous, Lignitic and Marine Tertiary, and in the Carboniferous. The only occurrence noted in the Carboniferous (although there are doubtless others) was at Cisco, Eastland county, where the lower shale, just below the coal, is of the proper composition to yield a buff-burning brick. The material, however, would have to be mined together with the coal.

Composition of Stoneware Clays, Texas.

Fusion Cone Number.	Color After Burning.	Chemical Composition.										Total Fluxes.
		SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	Total.	
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
...	Buff	69.56	15.69	2.87	2.38	2.0	0.77	0.87	1.2	5.0	99.84	8.29
...	Deep buff	70.00	18.7	1.2	0.5	1.2	tr.	1.5	1.0	6.1	99.2	6.4
15	Buff	65.64	20.48	1.44	1.7	0.32	1.0	0.6	0.27	7.5	98.95	5.06
27	Buff	68.3	20.1	1.0	tr.	2.4	tr.	0.6	1.2	6.6	100.2	4.0
25	Buff	64.92	22.7	0.8	0.10	0.74	0.12	0.71	1.4	7.0	98.49	2.87
27	Buff	68.84	21.15	1.15	tr.	tr.	0.45	1.12	1.22	6.62	100.55	2.72
27	Deep buff	74.3	16.0	1.4	tr.	......	0.5	0.6	0.5	2.7	98.60*a*	2.5
28	Buff	68.6	20.47	0.72	tr.	0.4	1.33	0.5	1.13	6.26	99.16	2.7
28	Whitish	70.00	17.78	0.14	tr.	0.18	0.73	1.08	1.4	6.36	99.03*b*	2.13
30	Whitish	72.22	17.93	0.43	0.1	0.65	tr.	0.29	1.5	6.26	99.38	1.47
27	Buff	78.22	8.71	0.72	3.36	1.1	0.45	1.17	0.17	5.5	99.4	6.8
29/30	Buff	71.57	17.12	1.65	0.15	0.95	0.38	0.88	1.25	5.8	99.75	4.01
27	Dark buff	72.00	16.39	0.57	0.5	1.4	tr.	0.84	1.05	6.1	98.85	3.31
27	Light buff	63.3	23.4	1.6	tr.	0.3	0.9	1.0	1.2	7.6	99.3	3.8
27	Buff	72.00	17.6	0.8	tr.	0.2	1.2	tr.	1.4	5.6	98.8	2.2
27	Buff	71.2	18.0	0.6	tr.	2.0	0.9	0.3	0.7	5.8	99.5	3.6
26	Deep buff	75.33	14.73	1.1	0.05	1.61	0.64	0.1	1.27	4.5	99.3	3.5
27	Buff	69.80	15.85	1.6	3.4	0.53	0.5	1.05	0.17	6.72	99.62	7.08
27	Pink buff	67.84	21.80	1.0	tr.	tr.	1.48	1.11	......	7.37	100.99	2.50

a Organic matter 3.7 per cent. *b* Organic matter 1.36 per cent.

Among the Cretaceous formations there are two areas supplying material of this class. One is the district along the Rio Grande at Minera, Webb county, the other at Denton, Denton county. At Minera and Cannel, beds of carbonaceous shale, from 2 to 3 ft. thick, are found underlying both coal-seams, and, owing to the thinness of the latter, more or less of the former also has to be removed in mining the coal. For some time this shale was allowed to accumulate on the dump, but since its value was recognized it has been shipped down to Laredo. While these shales burn to a good product, their frequently high content of carbonaceous matter and pyrite render it im-

portant that they should be well weathered before using. The economic value will continue only as long as these clays can be mined with the coal.

The clays found at Denton differ in character from the preceding, being of more desirable quality as well as better located for development. These clays occur in the Woodbine formation of the Upper Cretaceous; and the following section, from the pit of the Denton Pressed Brick Co., illustrates the mode of occurrence: blue clay, from 1 to 6 ft.; yellow-mottled clay, 5 ft.; greasy-gray clay, called "ball-clay," 4 ft.; black clay, from 2 to 3 ft.; and yellow-mottled bottom-clay, from 1 to 2 ft., with sand below.

This occurrence presents a series of beds, more or less dissimilar in physical characters and chemical composition (see Table VI.), so that the manufacturer, by selection or mixture, can produce a variety of results. The section is also interesting as showing the frequent change in character of the material deposited at this place.

The black clay represents the most common type found in the Woodbine formation. The others, according to Hill, are exceptional and confined to the region around Denton.

More important, however, are the clays of the Tertiary beds, which occur near the base of the Lignitic stage, associated with the lignite beds, as well as higher up in the series, and even in the Marine stage. Their distribution is, in fact, practically coextensive with the deposits described under stoneware and fire-clays, many of which can be, and some of which are already (as at Malakoff), used in the manufacture of pressed brick.

Those occurring interbedded with the lignites are usually shaly, often slightly carbonaceous, and the section given on p. — may be regarded as fairly typical of them. The value lies in the fact that, on account of the low iron-content, these clays burn at a comparatively low temperature to an agreeable buff color, as well as to a hard body. The depth below the surface is variable; at a few points the clays have been worked at the outcrop. The importance, however, will always be more or less dependent on the development of the lignite, since underground workings for the sake of the clay alone would not pay.

The other clays included in this group are those from Calaveras, Adkins and Rusk,—all occurring as lenticular deposits,

associated with sands, and on this account the point of mining operations would have to be shifted from time to time, if the demand for the clay were large. All three occurrences are somewhat semi-refractory, and the last two clays are quite siliceous,—in fact, contain sand-streaks. The properties of these clays are given in Table VI.

(b) *Red- and Brown-burning Brick-Clays.*—A considerable number of clay-deposits, scattered through the eastern half of Texas, are utilized for the manufacture of common or pressed red brick. These deposits probably represent a larger number of formations than those worked for any other kinds of clay-products in the State. The Carboniferous beds of northern Texas carry a number of beds of shale associated with the coal, and sometimes outcropping on the hill-slopes. These are worked at Thurber, Erath county; yield an excellent red brick for structural and paving purposes; and are also adapted to the manufacture of sewer-pipe. A section from the Bridgeport Coal Co.'s mine at Bridgeport, Wise county, illustrating the great abundance of shaly material in the Carboniferous beds, and its association with other kinds of sediments, shows: yellow sandy soil, 2 ft.; purple shaly clay, 3 ft.; whitish sandstone, 1 ft.; purple shaly clay, 10 ft.; blue shale, 70 ft.; limestone, 3 ft.; blue shale, 20 ft.; coal, 18 ft.; and bluish shale, 4 ft.

These Carboniferous shales probably represent one of the most important clay-resources of Texas; but they have not yet been thoroughly studied.

Next to the Carboniferous, the Upper Cretaceous contains a large quantity of red- or brown-burning clay, found in marls. It is probable that the Woodbine formation carries some clays of this character; but they are not worked.

The clays of the Eagle Ford, Taylor and Navarro formations resemble each other in some respects, being tough, dense, exceedingly plastic clays of low quality. Their peculiar character makes them the most difficult clays in the State to handle, since their great toughness interferes with their being molded by any wet method, and therefore they have to be pulverized and pressed in a dry or nearly dry condition. This is necessary also because it gives the brick a more open structure, and permits the burning-out of the carbonaceous matter in the

TABLE VI.—*Physical Tests and Chemical Composition*

Locality.	Laboratory Number.	Physical Tests. Tensile Strength (Average).	Air-Shrinkage.	Cone 1. (1150° C.) Fire-Shrinkage.	Cone 1. (1150° C.) Absorption.	Cone 5. (1230° C.) Fire-Shrinkage.	Cone 5. (1230° C.) Absorption.	Fusion-Cone Number.
		Lb. per Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
Cisco, Eastland Co.	944	208	6.6	3.7	6.5	5.4	0.421	...
Undershale, Minera, Webb Co.	802	167	10.1	.....	......	Vitrified.	......	14
Undershale, Cannel, Webb Co.	804	301	8.0	5.0	6.49	5.6	5.84	-27
Denton, Denton Co.	842	178	8.6	5.0	0.7	7.0	0.5	...
Denton, Denton Co.	843a	329	7.5	6.7	0.6	7.4	0.6	...
Denton, Denton Co.	844	318	8.0	5.7	0.1	7.0	0.5	...
Calaveras, Wilson Co.	810	191	6.9	6.7	5.49	5.0	0.76	27
Adkins, Bexar Co.	815	161	7.6	0.6	13.78	1.4	11.17	14
Rockdale, Milam Co.	814	291	6.7	1.7	8.41	2.0	6.01	27
Rockdale, Milam Co.	827	189	11.6	.....	......	.....	......	28
Rockdale, Milam Co.	829	302	9.1	4.3	5.7	4.0	4.65	27
Rusk, Cherokee Co.	856	261	10.3	2.3	9.35	6.3	5.0	27

[a] The analyses shows 16.6 per cent. of Fe_2O_3, which, if uniformly distributed,
large grains, and the clay therefore

clay. Most of these clays show a medium to high lime-content, which is, however, irregularly distributed, and therefore does not exert any important influence on the color of the brick. On account of the size of the clay-deposits in these two formations, they can be worked more economically than any others in the State. Fig. 3 shows the pit of a brick-works at Ferris, Ellis co., at which the Taylor marl is exploited.

At most localities the clay is weathered to the depth of from 10 to 15 ft. This mellowed material is far easier to treat, but, owing to its limited quantity, it is commonly mixed in mining with the underlying beds of unweathered clay.

The Eagle Ford clays are worked at Paris, Sherman and Dallas, and the Taylor-Navarro marls at New Boston, Cooper, Greenville and Corsicana. Those at Greenville are more siliceous, and the clay having a more open body is easier to mold and burn than that of the other localities named. Several analyses of these clays are shown in Table VII.

of Buff-Burning Non-Calcareous Brick-Clays, Texas.

Color After Burning.	SiO_2.	Al_2O_3.	Fe_2O_3	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	Total.	Total Fluxes.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Buff	62.26	23.78	2.02	tr.	0.10	1.16	1.59	1.40	7.12	100.43	5.87
Buff	63.00	23.00	2.5	tr.	1.1	1.7	0.3	1.3	4.8	97.7	5.6
Buff	57.00	22.2	2.1	0.25	tr.	tr.	0.21	1.31	6.65	99.72	2.56
Buff	57.00	25.59	3.44	0.96	0.72	0.94	0.82	0.87	10.00	100.34	6.98
Brown buff	51.5	17.6	16.6	1.00	1.1	1.5	tr.	1.6	7.7	98.60	20.2
Buff	56.2	23.7	1.5	0.6	1.5	1.4	2.2	1.6	11.1	99.8	7.2
Buff	70.5	18.3	1.8	tr.	0.9	tr.	0.2	1.2	5.5	98.4	2.9
Buff	68.7	15.9	3.3	3.1	0.5	tr.	0.3	1.4	5.9	99.1	7.2
Buff	77.00	15.87	1.26	1.10	0.37	......	......	0.87	4.5	100.97	2.73
Buff	64.00	22.59	1.22	0.88	1.15	tr.	0.06	1.51	5.80	97.22	3.31
Buff	67.00	19.68	0.72	0.62	1.06	tr.	1.18	1.82	6.07	97.15	2.58
Buff	82.45	10.92	1.02	0.22	0.96	......	......	1.00	2.47	99.10	2.26

would indicate a deep-red burning clay. The iron, however, is segregated in burns to a buff body with red spots.

Cretaceous clays are also worked about 3.5 miles east of San Antonio, but I am unable to say to which division of the Cretaceous these clays belong. In general character resemblance is shown to the Taylor-Navarro marls; except that numerous scattered bunches of selenite are present. So far as known, no deposits of clay are worked in the beds of the Will's Point stage.

The Lignitic clays, however, may prove valuable, and are already worked at Rockdale, where, overlying the lignites, red-burning, plastic, although somewhat siliceous, clays occur, which yield a red brick of excellent quality. At this place mining can be done from a surface-pit. Again, at Sulphur Springs, Hopkins county, and New Boston, Bowie county, there are red-burning shaly clays which may belong in the Lignitic stage, since the occurrence is well within its boundary, given on published maps. These clays differ much from the clay at Rockdale, being more shaly, bluish in color, and containing many concretions of limonite. Superficially some resemblance

TABLE VII.—*Physical Tests and Chemical Compo-*

Locality.	Geological Age.	Laboratory Number.	Physical Tests.							
			Tensile Strength (Average).	Air-Shrinkage.	Cone 05. (1050° C.) Fire-Shrinkage.	Cone 05. (1050° C.) Absorption.	Cone 1. (1150° C.) Fire-Shrinkage.	Cone 1. (1150° C.) Absorption.	Fusion-Cone Number.	Color After Burning.
			Lb. per Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.		•
Thurber, Erath Co.	Carboniferous.	846	181	6.4	2.3	6.47	4	4.74	0	Brown.
Bridgeport, Wise Co.		930	196	7.3	7.7	0.15	......	......	2	Brown.
San Antonio, Bexar Co.	Upper Cretaceous.	811	169	9.3	......	......	......	......	5	Red-brown.
Austin, Travis Co.		876	.....	......	......	......	......	.....	...	Red-brown.
Waco, McLennan Co.		946	182	5.3	0.7	15.82	5	2.81	8	Red-brown.
West Dallas, Dallas Co.		836	.....	This group of clays has an average air-shrinkage of 10.5%. The tensile strength ranged from 300–400 lbs. per sq. in. They all burn red-brown and fuse at cone 5–6. They have to be molded dry press.				......	...	....
8 m. W. of Dallas, Dallas Co.		841	.....					......	..	....
Sherman, Grayson Co.		875	.....					......	...	....
Paris, Lamar Co.		915	.....					......	...	....
Cooper, Delta Co.		921	.....					......	5–6	....
Ferris, Ellis Co.		839	.....					......	...	....
Corsicana, Navarro Co.		835	487	12.4	5.0	6.10	5.5	5.48	5	Red-brown.
Greenville, Hunt Co.		863	74	6.0	0.4	20.30	1.0	16.60	12+	Brown.
Vogel Mine, Rockdale, Milan Co.		830	304	9.3	1.0	12.09	2.7	7.87	12	Red.
Elgin, Bastrop Co.	Tertiary.	958	355	8.0	1.6	7.75	3.0	3.61	12	Brown-buff.
Sulphur Springs, Hopkins Co.		869	315	9.3	1.4	14.96	5.4	5.46	5	Red-brown.
New Boston, Bowie Co		860	192	11.6	6.3	2.73	12.20	5.77	5	Brown.
Houston, Harris Co.		826	316	9.3	0.4	6.63	0.8	5.43	5	Brown.
Houston, Harris Co.	Pleistocene.	824	159	10.1	0.7	15.29	4.0	8.82	3	Brown-buff.
Beaumont, Jefferson Co.		834	303	9.4	0.3	10.53	0.3	9.39	9	Brown.

to the Navarro marl is shown; but the clays are less plastic, less calcareous, and more easily worked; possibly representing Upper Cretaceous islands, projecting through the Tertiary. At points intermediate between Sulphur Springs and Rockdale, either stoneware- or fire-clays, and no red-burning Lignitic clays are worked. Since many railroads cross the Lignitic belt, it would be desirable to prospect further for clays of this class, since those developed hitherto are more valuable than the Eagle Ford or Navarro-Taylor marls.

No red- or brown-burning brick-clays are worked in the other Tertiary areas, southeast of the Lignitic. Doubtless such

sition of Red- or Brown-Burning Brick-Clays, Texas.

Chemical Composition.

SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	Miscellaneous.	Total.	Total Fluxes.
Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.		Per Cent.	Per Cent.
68.75	15.81	4.05	0.60	1.64	tr.	0.08	0.60	4.07	Org., 2.10	97.70	6.87
59.20	20.60	6.90	1.08	1.69	1.6	1.84	1.5	4.66	Org., 0.2	99.20	13.04
59.47	18.24	4.77	4.3	tr.	tr.	0.24	1.14	5.70	CO_2, 525 ; SO_3, 0.90 ; Org., 0.55	98.56	9.31
54.5	22.6	6.20	0.54	1.15	1.4	1.55	1.22	6.2	Org., 4.5	99.86	10.84
72.36	7.84	1.72	6.48	2.28	1.2	1.7	0.12	3.72	CO_2, 3.30	100.67	13.38
58.70	21.78	5.49	1.06	1.24	0.32	0.18	1.18	5.88	Org., 3.0 ; SO_3, 0.83	99.06	8.29
53.21	22.83	6.48	1.70	1.72	tr.	0.05	1.75	7.06	Org., 2.0 ; CO_2, 3.10	....	9.95
59.34	15.71	5.76	3.00	2.09	0.56	1.44	1.88	7.02	CO_2, 1.07 ; SO_3, 0.31 : Org., 2.00	100.18	12.85
64.2	20.13	1.87	0.34	1.62	0.69	1.78	2.00	5.32	Org., 0.1; SO_3, 1.8	....	....
53.48	17.84	3.16	8.08	1.44	0.85	1.6	1.0	6.9	CO_2, 4.66	99.01	15.13
49.60	16.06	5.60	10.66	2.14	1.38	0.77	0.7	5.02	SO_3, 7 ; CO_2, 6.94	99.39	19.95
55.28	21.27	8.87	3.90	0.28	......	tr.	1.05	4.26	CO_2, 3.30 ; Org., 1.43	99.14	12.55
79.00	11.88	2.44	0.50	0.20	0.35	0.65	0.78	3.80	....	99.0	4.14
72.9	14.7	4.5	0.6	0.3	1.5	0.7	1.0	4.2	....	99.5	7.6
70.4	17.3	1.8	1.0	tr.	0.6	2.2	0.8	5.4	....	99.5	5.6
69.36	14.67	4.46	0.28	1.74	1.55	2.09	1.13	3.64	Org., 0.96; SO_3, tr.	99.88	10.12
66.01	18.82	6.33	0.55	1.88	0.16	0.08	0.95	4.8	....	99.51	9.00
72.45	11.72	3.38	3.66	1.34	tr.	0.19	0.87	3.44	CO_2, undetermined.	97.05	8.57
49.40	17.90	4.50	9.50	1.88	......	tr.	1.05	4.58	CO_2, 9.55	98.36	15.88
77.96	11.04	3.19	0.84	0.38	......	......	1.23	3.24	SO_3, 0.51	98.40	4.41

exist, but the relative remoteness of the region from the main lines of transportation, and from the larger cities of the State, does not encourage development.

Of the Pleistocene clays there are many deposits, mostly rather siliceous. The better ones are to be sought in the area of the Beaumont clays, described on an earlier page. These seem, however, to be so variable in character that it is difficult to generalize the properties. All these clays are red- or brown-burning; but in chemical composition, shrinkage, fusibility, and other physical qualities, much variation is shown. Moreover, objectionable inclusion of lime-pebbles

frequently occur. Nevertheless, these clays are the only important source of brick-clay for the cities of Houston, Beaumont, and others in that region; and, if care be used in selection, a good product can be obtained. Analyses Nos. 824 and 826 in Table VII., both of clay from Houston, afford an excellent example of the difference in chemical composition of clay from adjoining yards.

(c) *Calcareous Brick-Clays.*—This class includes clays from dfferent parts of the State, nearly all of which are used for brick. Excepting a Cretaceous clay southeast of Austin, all of those examined are Pleistocene alluvial deposits, underlying the terraces and flats along the rivers, especially the larger ones, such as the Colorado, Rio Grande, Brazos, etc. The two following sections (1) from the river terrace at Austin, Travis county (Fig. 9), and (2) from Wharton, Wharton county, may illustrate their occurrence:—

1. From the river-terrace at Austin: surface-soil, 1 ft.; silty clay, 7 ft.; and red, plastic clay, 16 ft., with gravel and sand below.

2. From Wharton, Wharton county: soil, 1 ft.; yellow clay, 3.5 ft.; chocolate clay, 1.5 ft.; yellowish clay, 15 ft.

Such sections, however, have no permanent value, since they change from day to day as the excavation uncovers different parts of the deposit. This variation is the result of the conditions of deposition. In order to preserve a general average quality of product, the "run of the bank," *i.e.*, the product of a section through all layers, is usually shipped. At some localities the terrace-level is not above high water, and during periods of flood a fresh layer of silt, sometimes several inches in thickness, is deposited. This recent deposit may be quite different from the earlier ones, as at Gonzales, where the terrace-silts worked for brick are calcareous, while the present sediment of the river is ferruginous.

The calcareous silts are widely distributed throughout eastern Texas, and, on account of the ease of excavation and manipulation, this class of material is much used. The peculiar physical and chemical characters warrant the placing of the calcareous clays in a group by themselves. Summarizing the physical characteristics, we may say that but little water is absorbed and the plasticity is usually low; but the tensile strength

is remarkably high. Of 17 samples tested, 8 showed an average of more than 300 lb., and 5 others exceeded 200 lb., per sq. in. Many exhibited high air-shrinkage, but all showed low fire-shrinkage and high porosity, until close to the vitrifying-point, when the body condensed suddenly. In the chemical analyses, the low silica-content, the high lime, and the usually high total fluxes, are specially noticeable. The percentage of lime is often astonishingly high; that of magnesia, on the other hand, is rarely so; and of the alkalies, soda averages higher than potash. Titanic acid is usually present, but rarely in excess of 1 per cent.

Interesting comparisons are afforded by an inspection of the totals of fluxes and the fusion-points. There does not appear to be even an approximate relation between the two. This is, no doubt, due to differences in texture, a coarse grain counterbalancing a high percentage of fluxes.

As is well known, calcareous clays are very porous after burning at low temperatures and before fire-shrinkage begins. This degree of porosity appears to be in direct relation, not to the amount of CO_2 present, but rather to the combined percentages of CO_2 and H_2O.

The calcareous clays are much worked in Texas for making common brick, pressed brick, and some drain-tile. Laredo and Austin are the most important localities.

(d) *Sandy Brick-Clays.*—These represent the poorest quality of material used for the manufacture of clay-products in Texas. The clays are sandy, or rather clayey sands, usually of Pleistocene age, although possibly a few may belong to the Tertiary. In some instances, as at Longview and Harrisburg, the clay is interstratified or underlain by a bed of more plastic clay, which is mined with it. It might be sufficient to pass these materials by, with no further statement than to refer to the use for common brick; but the tabulated summary of the tests in Table IX. is not without interest. The high percentage of silica is, perhaps, the most prominent feature of the composition; and it seems remarkable that a material carrying from 85 to 90 per cent. of silica should possess sufficient plasticity to permit of its being molded into bricks.

The alumina is variable. If we assumed most of it to be present as kaolinite, it would indicate that at least 70 or 80 per

TABLE VIII.—*Physical Tests and Chemical*

Locality.	Laboratory Number.	Physical Tests.						
		Tensile Strength. (Average.)	Air-Shrinkage.	Cone 1. (1150° C.)		Cone 5. (1230° C.)		Fusion-Cone Number.
				Fire-Shrinkage.	Absorption.	Fire-Shrinkage.	Absorption.	
		Lb. Pe Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
Laredo, Webb Co.	806	149	4.7	-1.0	19.34	4.3	8.3	7
D'Hannis, Medina Co.	910	259	8.3	-0.4	19.63	......	....	1
Calaveras, Wilson Co.	809	366	6.7	0	....	1.3	....	6
Seguin, Guadeloupe Co.	818	301	6.0	-1.3	....	-1.0	....	...
Gonzalez, Gonzalez Co.	816	357	8.3	1.0	23.11	1.3	22.15	7
Gonzalez, Gonzalez Co.	817	201	6.5	0.7	26.49	0	25.53	7
Austin, Travis Co.	801	253	6.2	-0.7	....	1	23.49	7
8⅜ m. E. of Austin, Travis Co.	945	225	10.6	7.3	12.3	......	....	5-6
Wharton, Wharton Co. Different layers.	901	119	0	-0.6	21.63	0	16.51	9
	902	330	10	0	12.01	......	....	1
	903	308	6.6	-0.7	16.77	......	....	1
Taylor, Williamson Co.	911	153	4.5	-1.0	54.5	-1	48.59	...
Brenham, Washington Co.	873	355	12.8	......	....	......	....	3
Belton, Bell Co.	918	340	6.6	0	21.92	0	21.1	...
Waco, McLennan Co.	947	205	6	-0.3	15.01	7.4	3.5	2

cent. of the clay is sand and the balance clay. The fluxing materials are all low (having been mostly leached out, if they were ever present), and what iron oxide there is forms a coating around the quartz-grains. Titanium is rather high. In spite of the siliceous character, some of these clays (as, for example, those from Elgin and Winnsboro), show a remarkably high tensile strength when air-dried, and all show the low fire-shrinkage characteristic of sandy clays, some even swelling slightly at the lower temperatures, because of the high silica-eontent. A careful comparison of the chemical analyses and physical properties will, as usual, show that the former give us but little information regarding the latter. Table IX. gives the physical and chemical properties of a number of samples examined.

(e) *Paving-Brick Clays.*—Only one factory in Texas now produces paving-bricks, most of the supply being brought from

Composition of Calcareous Brick-Clays, Texas.

Color After Burning.	Chemical Composition.											
	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	CO_2.	Total.	Total Fluxes.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Buff	59.03	11.19	2.77	12.16	0.8	tr.	0.18	1.05	2.1	9.6	98.88	15.91
Brown buff	51.12	11.04	4.1	14.24	0.9	0.4	1.59	0.96	4.0	10.62	98.87	21.23
Buff	37.45	7.72	2.02	27.92	0.36	......	......	tr.	2.4	21.8	99.67	30.3
Brown buff	18.62	3.23	1.26	41.30	0.42	......	......	tr.	2.42	32.5	99.75	42.96
Buff	37.05	8.13	1.8	25.3	2.23	tr.	0.08	0.47	2.64	22.12	99.82	29.41
Brown buff	41.2	6.5	1.98	24.4	1.62	0.09	0.14	0.43	2.28	20.63	99.27	28.23
Brown buff	53.6	9.0	2.6	17.8	1.2	1.8	tr.	0.8	1.0	11.6	99.4	23.4
Buff	34.6	15.02	3.02	21.48	0.15	1.43	1.43	0.96	6.0	15.6	99.6	27.42
Brown buff	65.92	10.57	1.94	9.33	1.23	......	......	0.90	2.65	7.66	100.2	12.5
Brown buff	63.56	8.18	4.32	10.0	0.15	tr.	1.0	0.95	4.16	7.36	99.68	15.47
Brown buff	65.07	9.16	2.8	8.44	0.21	0.5	1.66	1.05	3.72	6.92	99.53	13.61
Buff	21.72	7.97	2.23	36.54	0.95	tr.	tr.	0.52	2.06	28.44	99.73	39.72
Brown buff	51.3	14.4	6.2	10.3	tr.	tr.	4.1	0.8	4.9	7.6	99.6	20.6
Buff	47.2	4.1	2.4	21.0	1.4	tr.	1.3	0.7	2.9	18.1	99.1	26.1
Brown buff	71.4	8.2	2.3	6.34	2.44	1.22	1.6	0.14	3.25	3.7	100.59	14.9

other States. This has naturally raised the question whether suitable clays are scarce in Texas. Few have been found hitherto, and all of these are in the Carboniferous, no clays of vitrifying quality having been observed in the Cretaceous, Tertiary or Pleistocene, east of the 99th Meridian. Those now known come from Graham, Young county, and Thurber, Erath county, and agree in being of dense-burning character, low fusibility and high plasticity. Up to the present time only those at Thurber have been worked. Here two distinct beds are found, the one being near the summit of what is known as No. 1 Hill, and at least 75 ft. higher than the coal, while the other is found almost immediately below the surface over a large area in the valley to the north of the brick-works.

Table X. shows the tests and analyses of the paving-brick clays.

TABLE IX.—*Physical and Chemical*

Locality.	Laboratory Number.	Physical Tests.						
		Tensile Strength. (Average).	Air-Shrinkage.	Cone 05. (1050° C.) Fire-Shrinkage.	Cone 05. (1050° C.) Absorption.	Cone 1. (1150° C.) Fire-Shrinkage.	Cone 1. (1150° C.) Absorption.	Fusion-Cone Number.
		Lb. Per Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	
Elgin, Bastrop Co.	959	455	9.6	0.4	9.58	2.3	5.78	9
Fulshear, Fort Bend Co.	937	183	5.6	0	12.82	0.3	12.29	...
Houston, Harris Co.	825	260	6.2	-0.6	10.12	-0.6	9.41	12+
Top and middle bed, Harrisburg, Harris Co.	821	188	4.8	-0.3	14.83	-0.3	14.38	...
Lower bed, Harrisburg, Harris Co.	823	275	8.6	0.3	9.98	0.3	9.95	9
Cedar Bayou, Chambers Co.	866	200	6.6	-0.7	12.04	0	12.56	...
Colmesneil, Tyler Co.	904	77	4.0	-0.8	9.14	0	9.45	14+
Giddings, Lee Co.	909	234	4.3	-0.4	11.20	-0.3	11.03	9
Cleburne, Johnson Co.	922	128	4.0	0	13.58	-0.7	13.68	...
Rusk, Cherokee Co.	857	207	9.6	0.4	13.41	1.7	10.82	14
Winnsboro, Wood Co.	865	315	6.0	0	10.69	0	10.62	14+
Top and middle layer, Longview, Gregg Co.	905	177	10.3	0.6	15.01	3.7	10.45	14-15
Lower layer, Longview, Gregg Co.	906	206	10.5	0.7	14.63	3	8.80	14
Detroit, Red River Co.	920	262	10.3	0	9.73	0.7	9.93	9
Marshall, Harrison Co.	907	122	3.3	-0.3	13.74	0	12.96	14+
Texarkana, Bowie Co.	859	117	6.6	0	11.77	0	13.27	14+

4. *Slip-Clays.*

At several localities beds of clay are found, which, on account of the high percentage of fluxing-impurities, especially alkalies, fuse at a comparatively low temperature, and run to a colored glass or natural glaze. Clays of this type are used for glazing stoneware, and their discovery is always of importance, since the main source of supply of American slip-clay is New York State, whence the material is shipped to many parts of the country. All of the slip-clays found during the field-work of the survey belong to the Pleistocene, with one exception, which is Carboniferous.

The Texas slip-clays occur in beds of variable thickness, interstratified with sands or other clays, and there is nothing in the appearance to indicate the easily fusible character. It

Analyses of Sandy Brick-Clays, Texas.

Color After Burning.	Chemical Composition.										
	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	Total.	Total Fluxes.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Red-brown	72.9	9.5	4.1	4.1	0.8	2.4	tr.	0.6	4.5	99.1	11.4
Brown	83.80	9.23	2.3	tr.	tr.	0.56	0.54	0.87	3.1	100.4	3.4
Red	89.00	3.69	1.65	0.47	0.65	tr.	0.06	0.84	1.64	97.98	2.83
Red	80.39	9.82	2.88	0.42	0.45	tr.	0.19	0.35	3.11	97.61	3.94
Red	80.84	8.09	2.25	1.44	0.26	tr.	0.10	0.78	6.0	99.76	5.15
Red-brown	85.60	6.71	1.44	tr.	0.43	0.5	0.65	1.0	3.1	99.43	3.02
Brown	90.00	4.5	1.44	0.1	0.1	tr.	tr.	0.7	3.04	99.98	11.64
Brown	81.50	5.43	3.6	1.3	0.25	0.49	1.56	0.87	4.0	99.	7.2
Brown	87.3	4.06	3.52	1.03	0.13	tr.	0.2	0.48	2.44	99.13	4.85
Brown	72.76	14.46	3.31	0.08	1.93	tr.	tr.	1.43	4.61	99.08	5.82
Brown	85.35	6.72	1.87	0.4	0.24	tr.	0.2	1.01	3.2	98.99	2.71
Brown	73.06	9.88	6.92	1.5	0.25	tr.	0.12	1.0	6.64	99.37	8.81
Brown	68.5	18.41	3.02	0.7	1.05	0.47	0.91	1.31	6.2	100.57	6.15
Brown	78.5	10.5	3.6	0.45	0.23	0.9	0.4	0.32	4.22	99.12	5.58
Red-brown	83.9	5.52	4.75	0.4	1.32	0.15	0.45	1.57	2.44	100.5	7.07
Red	88.71	4.88	2.0	0.3	0.97	tr.	tr.	0.9	2.28	100.04	3.27

is therefore only by accident or detailed investigation that the special qualities have been recognized; and, in a few instances, have become known to potters.

Such clays have thus far been found near Carmona, Polk county; Navasota, Grimes county; San Antonio, Bexar county; and Bridgeport, Wise county. That near San Antonio is perhaps the best known, and is found outcropping in the banks of Alazan creek, the section showing: black soil, 2.5 ft.; impure, yellow, gravelly clay, 2.5 ft.; and yellowish-brown slip-clay, 7.5 ft., with sand below.

The same type of clay outcrops again on the Leon creek, 7 miles south of San Antonio.

The slip-clay northeast of Navasota is a white chalk-like material, occurring in beds from 6 to 8 ft. thick, with but little

TABLE X.—*Physical Tests and Chemical*

Locality.	Laboratory Number.	Physical Tests.						
		Tensile Strength. (Average.)	Air-Shrinkage.	Cone 05. (1050° C.)		Cone 1. (1150° C.)		Fusion-Cone Number.
				Fire-Shrinkage.	Absorption.	Fire-Shrinkage.	Absorption.	
		Lb. Per Sq. In.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
M. K. Graham property, Graham, Young Co.	880	197.5	6.1	7.7	4.5	8.6	0.90	9
W. D. & C. H. Craig property, 16 m. W. of Graham	879	200	7.3	3	8.85	6	1.54	9
14 m. W. of Graham, Young Co.	878	188.3	6.2	2.7	10.91	8	0.13	9
Thurber, Erath Co., No. 1 Hill	847	299	8	5	4	5.3	0.14	3
Thurber, Erath Co., Valley Clay	......	383	7.7	5.6	3.58	6.3	01.0	5

overburden; that found 2.5. miles southeast of Carmona is at least 6 ft. thick, with little overburden; thus, in every instance, the deposits are sufficiently thick to supply a large demand. Table XI. gives the analyses of the Texas slip-clays.

IX. THE TEXAS CLAY-WORKING INDUSTRY.

In 1904, the clay-products of Texas placed it the eighteenth in that department among the States of the Union, most of its product consisting of common building-brick, made chiefly for local use. Some pressed brick, paving-brick, stoneware, fire-brick and drain-tile were also made; but the quantity was small. Sewer-pipe, terra-cotta, fire-proofing, conduit- and floor-tiles were not made at all.

The prominence of a State as a manufacturer of clay-products, depends not only upon its suitable raw material, but also upon its available markets. Texas has the former in abundance, and as to the latter, it may be said that the demand is increasing, but is still largely supplied by establishments outside of the State. It remains, therefore, for enterprising parties to develop the clays, and not only get control of the local markets, but supply those of the other Gulf States and Mexico as well.

Composition of Paving-Brick Clays, Texas.

Color After Burning.	Chemical Composition.											
	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	TiO_2.	H_2O.	Moist	Total.	Total Fluxes.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Buff..................	63.8	24.5	1.3	0.1	0.2	2.3	1.3	1.0	6.2	2.6	100.1	5.2
Light brown....	......	......	......	......	......	Not	analy	zed.	......	......	......	......
Brown..............	60.5	19.4	9.3	tr.	0.3	1.4	1.5	0.6	6.8	2.8	99.5	12.5
Brown..............	64.52	17.72	4.46	0.27	1.58	2.71	1.24	1.30	5.44	......	99.24	10.2
Red-brown	63.07	19.48	4.75	1.32	1.50	......	......	1.47	6.90	0.19	99.09	6.57

TABLE XI.—*Analyses of Slip-Clays, Texas.*

	2 m. S. W. of Carmona, Polk Co.	Leon Creek, San Antonio, Bexar Co.	Alazan Creek, San Antonio, Bexar Co.	13 m. N. of Navasota, Grimes Co.	Bridgewater, Wise Co.
Laboratory No.	950	949	924	951	930
SiO_2................	63.34	38.08	57.01	68.56	59.20
Al_2O_3.............	15.28	11.36	11.85	18.53	20.60
Fe_2O_3.............	3.44	2.6	3.02	0.72	6.90
CaO................	1.20	23.70	9.56	0.60	1.08
MgO................	0.88	tr.	1.20	0.12	1.60
K_2O................	2.4	0.58	0.75	2.27	1.60
Na_2O...............	3.55	1.6	2.01	2.72	1.84
TiO_2...............	0.52	0.7	1.13	0.43	1.50
H_2O................	4.7	3.06	4.00	7.00	4.66
CO_2................	......	18.80	8.00	......	......
Total...............	100.38	100.44	98.53	100.95	99.00
Total fluxes......	11.54	28.48	16.54	6.45	13.04

SUBJECT TO REVISION.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Notes on the Roumanian Oil-Fields.

BY P. CHARTERIS A. STEWART, CAIRO, EGYPT.

Presented at the Bethlehem Meeting, February, 1906, and published in *Bi-Monthly Bulletin*, No. 10, July, 1906.

POSTSCRIPT.*—For the better understanding of my paper on Roumanian Oil-Fields, it would be well if the following list of Roumanian formations were added, since the terms used in the text are more or less peculiar to Southeastern Europe.

TABLE IV.—*Rocks Connected with Oil-Bearing Formations.*

Neogene.	Levantin.	Candeshti beds.
		Unio sculptées beds.
	Pontic.	Vivipara bifarcinata beds.
		Congeries beds.
		Meotic.
		Sarmatian.
		Saline Sub-Carpathian.
Paleogene.	Oligocene.	Kliva Grits.
		Menilite Schists (Shipota beds).
	Eocene.	Targu Ocna beds.
		Saline Paleogene.
		Eocene.

* Received July 20, 1906.

AMERICAN INSTITUTE OF MINING ENGINEERS

ORGANIZED 1871

INCORPORATED 1905

No. 12. NOVEMBER. 1906.

Bi-Monthly Bulletin

OF THE

American Institute of Mining Engineers.

PUBLISHED BY THE AMERICAN INSTITUTE OF MINING ENGINEERS

At S.-W. Cor. Seventh and Cherry Sts.

PHILADELPHIA, PA.

EDITORIAL OFFICE AT 99 JOHN STREET, NEW YORK, N. Y.

Entered December 6, 1904, at Philadelphia, Pa., as second-class matter under Act of Congress of July 16, 1894.

Bi-Monthly Bulletin

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SECTION I.

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This section contains announcements of general interest to the members of the Institute, but not always of sufficient permanent value to warrant republication in the volumes of the *Transactions*.

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BI-MONTHLY BULLETIN.

For the convenience of persons who desire to file, or otherwise use separately, the technical papers in Section II. of the Bulletin, each of these papers has been paged and wired by itself; the whole collection being held together by a single, heavy wire, upon the removal of which it will fall apart into individual pamphlets, substantially like those formerly issued.

A small stock of separate pamphlets, duplicating the technical papers given in Section II. of this Bulletin, is reserved for those who desire extra copies of any single paper.

All communications concerning the contents of this Bulletin should be addressed to Dr. Joseph Struthers, Assistant Secretary and Editor, 99 John St., New York City (P. O. Box 223; Telephone number 5477 John).

UNITED ENGINEERING SOCIETY'S BUILDING.

This building is so near completion in every respect that the Trustees expect to take possession of it December 15, and it may be anticipated that the three Founder Societies will occupy their respective quarters in it before January. The official "house-warming" will take place at a considerably later date, to be hereafter announced.

Under these circumstances, it is deemed unnecessary to give here any detailed report of the present condition of the work. Full particulars will doubtless be published in the *Bi-Monthly Bulletin*, No. 13, January, 1907.

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PUBLICATIONS NEEDED TO COMPLETE SETS IN LIBRARY.

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Berg und Hüttenmännisches Jahrbuch der K. K. Bergakademien zu Leoben und Pribram.

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Canadian Mining Review.

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Canadian Naturalist and Geologist.

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COLORADO—MINES BUREAU. *Report.*

Wanting: All before 1896 and 1898.

COLORADO SCIENTIFIC SOCIETY. *Proceedings.*

Wanting: Vol. 1 (1883) and pp. 40-54, Vol. 7.

Compressed Air.

Wanting: Vol. 1 (1896), Nos. 2, 7-12; Vol. 2, Nos. 2-3 and 12; Vol. 3; Vol. 4, Nos. 1-2, 10-12; Vol. 5.

DEUTSCHE CHEMISCHE GESELLSCHAFT. *Berichte.*

Wanting: Vols. 1-12 (1868-'80).

Dingler's Polytechnisches Journal.

Wanting: Vols. 1-54 (1820-'36); Vols. 59-72; Vols. 75-94; Vols. 99-102 Vols. 123-126; Vols. 192-201; Vol. 249, Pt. 4; and Vols. 250-date.

EDINBURGH GEOLOGICAL SOCIETY. *Transactions.*

Wanting: Vols. 1, 3 and 4.

Eisen-Zeitung.

Wanting: Years 1-24 (1880-1903).

Electrochemische Technik. Gross-Lichterfelde, Ost, Germany.

Wanting: Pts. 1-25, 1902-Oct. 1904.

Elektrochemische Zeitschrift, Berlin.

Wanting: Years 1-9 (1894-1903).

The Engineer.
Wanting: Vols. 1–51 (1856–'81); Vols. 57–58; Vol. 78; index and title page to Vols. 54, 60, 68, 71, 88 and 92; No. 34 of Vol. 52, and (July–Aug. 2d and Oct. 11–end of Dec. 1889) of Vol. 68.

ENGINEERING ASSOCIATION OF NEW SOUTH WALES. *Proceedings.*
Wanting: Vols. 12–17.

Engineering.
Wanting: Vol. 1 (1866).

Engineering Magazine.
Wanting: Vol. 1, Nos. 1, 2, 5–6 (1891).

Engineering News and American Railway Journal.
Wanting: Vol. 1 (1874); Vols. 3–6; Vols. 10 and 23.

Engineering Record, Building Record and Sanitary Engineer.
Wanting: Vols. 1–44 (1877–1901).

Engineering Review, London. (Formerly Feilden's Magazine.)
Wanting: Vols. 1–8 (1894–1902).

Engineering Review, London.
Wanting: Vol. 2, Nos. 7 and 10 (1894).

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA. *Proceedings.*
Wanting: Vol. 16 (1900).

FOUNDRY.
Wanting: Vols. 1–22 (1892–'1902), and Vol. 23, to No. 133 (1903).

Geological Magazine, London.
Wanting: Vol. 4–date (1867–date).

GEOLOGICAL SOCIETY OF SOUTH AFRICA. *Transactions.*
Wanting: Vol. 1; Vol. 2, Pts. 1 and 2; Vol. 5.

GEORGIA—GEOLOGICAL SURVEY. *Bulletin.*
Wanting: No. 1.

GEOGRAPHICAL SOCIETY OF PHILADELPHIA. *Bulletin.*
Wanting: Vols. 1–2 (Jan., 1893–Jan., 1895 and May, 1896–Dec., 1900).

Giesserei-Zeitung.
Wanting: Vol. 1, Nos. 1–18, and 19–end of Vol.

Glückauf.
Wanting: All before 1896; 1899 (Dec. 23, No. 52); 1900 (June 20, No. 27); 1901 (Jan. 1).

GREAT BRITAIN—GEOLOGICAL SURVEY AND MUSEUM OF PRACTICAL GEOLOGY. *Memoirs.*
Wanting: Vol. 3.

GREAT BRITAIN—MINING RECORD OFFICE. *Mineral Statistics of the United Kingdom and Ireland.*
Wanting: 1857, 1858, Pt. 1.

GREAT BRITAIN—PATENT OFFICE. *Illustrated Official Journal*
Wanting: Nos. 1–747.

ILLINOIS—GEOLOGICAL SURVEY (1866–'90).
Wanting: Vol. 5.

INDIA—BUREAU OF MINES INSPECTION. *Report of the Chief Inspector.*

Wanting: All before 1901.

INDIA—GEOLOGICAL SURVEY, *Memoirs.*

Wanting: Vol. 1; Vol. 10, Pts. 2–4; Vols. 11–13; Vol. 15, Pts. 2–4; Vols. 16–33.

——— *Records.*

Wanting: Vols. 7–10 (1873–'77); Vol. 12, Pts. 2–4; Vols. 13–31.

Indian and Eastern Engineer.

Wanting: New Series, Vol. 4, No. 4 (April, 1899); Vol. 5, Nos. 2 and 4–5 (Aug., Oct. and Nov., 1899); Vol. 6, Nos. 2, 4 and 5; Vol. 7, Nos. 1 and 2; Vol. 8, No. 4; Vol. 9, Nos. 1, 5 and 6; and from Nov., 1901–date.

INDIAN TERRITORY—MINE INSPECTOR. *Annual Reports.*

Wanting: 1897, 1901.

INSTITUTION OF CIVIL ENGINEERS. *Minutes of Proceedings.*

Wanting: Vols. 1–12 (1837–'53).

INSTITUTION OF ELECTRICAL ENGINEERS. *Journal.*

Wanting: Vols. 1–30, and Vol. 31, Pts. 2–3 (1872–1899).

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND. *Transactions.*

Wanting: Vols. 1–38 (1857–'94); Vols. 40–43.

INSTITUTION OF MECHANICAL ENGINEERS. *Proceedings.*

Wanting: 1847–'78.

INSTITUTION OF NAVAL ARCHITECTS. *Transactions.*

Wanting: Vols. 1–34 (1860–'94).

IOWA—GEOLOGICAL SURVEY. *Annual Report.*

Wanting: Vol. 6.

IOWA—STATE MINE INSPECTOR. *Biennial Report.*

Wanting: 1st, 8th, 9th and 10th.

Iron Age.

[NOTE.—From 1855–1859 the title of "The Iron Age" was "Hardware-Man's Newspaper and American Manufacturers' Circular." Monthly. Seven numbers were published from 1855–1856; a new series of three volumes from 1856–59. It was continued under the title of "Iron Age" with slight variations from 1859 to date.]

Wanting: Vols 1–23; Vol. 44 (Nov. 21, 1889); Vol. 45 (Feb. 6, 1890); Vol. 48 (September 24, 1891, and index); Vol. 63, No. 24; Vol. 67, index.

Iron and Coal Trades Review, London.

Wanting: Vols. 1–28 (1870–'83); Vols. 47 and 48.

IRON AND STEEL INSTITUTE. *Journal.*

Wanting: 1890–'95, 1897, 1902–'03.

——— *Transactions.*

Wanting: Nos. 2–4 (1869–'70).

The Ironmonger.

Wanting: All before 1881; March 29 and July 5, 1890; 1902–May, 1904 inclusive.

Iron, the Journal of Science, Metals and Manufactures.
Wanting: Vols. 1–13 and 27.

Iron Trade Review.
Wanting: Vols. 1–27; Vol. 28, Nos. 1–41; Vol. 31; Vol. 34, Nos. 2 and 11, and indexes to Vols. 28 and 34.

Jaarboek van het Mijnwezen in Nederlandsch Oost-Indie, Batavia.
Wanting: Years, 1–30.

Jahrbuch der Chemie, Meyer.
Wanting: Vols. 7–date (1897–date).

Jahrbuch der Elektrochemie.
Wanting: Years 10–date (1903–date).

Jahrbuch der Kaiserliches-Königlichen Geologischen Reichsanstalt.
Wanting: Vol 11, (1860); Vols. 22–28 (1874–'78).

Jahrbuch für das Berg und Hüttenwesen in K. Sachsen.
Wanting: 1826–'75 and 1877.
(1827–'51 title reads Kalender für den Sachsischen Berg und Hüttenmann. 1852–'72, title reads Jahrbuch für den Berg und Hütten-mann.)

Jahres-Bericht über die Leistungen der Chemischen Technologie.
Wanting: Vols. 1–12 (1855–'66); Vols. 16–18 (1870–'72).

Jern-Kontorets Annaler, Stockholm.
Wanting: Vols. 1–2 (1817–'18); Vol. 4; Vol. 10, Pt. 2; Vols. 12–13; Vols. 16–31; Vol. 54, Pt. 1.

Journal de l'Electrolyse.
Wanting: Years 1–12 (1891 (?)–1903); Year 13 (all of Jan., 1904, and Nos. 183–184, 186, 195, 198 and 200.

Journal of the Military Service Institution of the United States.
Wanting: Vol. 1 and Vols. 9–27.

JUNIOR INSTITUTION OF ENGINEERS. *Record of Transactions.*
Wanting: Vol. 1.

KAISERLICH KÖNIGLICHE GEOLOGISCHE REICHSANSTALT. *Verhandlungen.*
Wanting: All before 1867, 1868–'79, 1881–'83.

KANSAS—STATE INSPECTOR OF COAL MINES. *Annual Report.*
Wanting: 1–2, 8, 10–date.

KENTUCKY—GEOLOGICAL SURVEY. *Report on the Progress of the Survey.*
Wanting: 1873–'82.

——— ——— New series.
Wanting: Vols. 1–2, 4–5.

London, Edinburgh and Dublin Philosophical Magazine and Journal of Science.
Wanting; Ser. 4, Feb., 1875–date.

LOUISIANA—GEOLOGICAL SURVEY. *Geology and Agriculture.*
Wanting: Pts., 1–2.

LYCEUM OF NATURAL HISTORY OF NEW YORK. *Annals.*
Wanting: Vols. 1–10 (1823–'76) and Vol. 11, Nos. 1–6.

MANCHESTER GEOLOGICAL SOCIETY, ENGLAND. *Transactions.*
Wanting: Vols. 1–14.

MANITOBA HISTORICAL AND SCIENTIFIC SOCIETY, WINNIPEG. *Transactions.*
Wanting: Nos. 6, 14, 16, 18, 23, 32, 34, 39, 44, 51.

MASTER CAR BUILDERS' ASSOCIATION. *Report of the Proceedings of the Annual Convention.*
Wanting: Vols. 1–15, Vol. 17, Vols. 26–27 and Vol. 35.

MECHANICS' INSTITUTE OF THE CITY OF SAN FRANCISCO. *Report of the Industrial Exhibition.*
Wanting: Reports 1–3 and 6.

Mechanic's Magazine. (Continued as Iron, the Journal of Science, Metals and Manufactures from 1873–).
Wanting: Vols. 7–69, (1828–'58) and new series (1859–'72).

Metal Industry.
Wanting: Old series, Vols. 1–8.

Der Metallarbeiter, Vienna.
Wanted: Vols. 1–28 (1874–1903).

La Metallurgie, Paris.
Wanting: All before Feb. 12, 1902; Vol. 33, Nos. 1–8, 10 and 23.

MICHIGAN—GEOLOGICAL SURVEY. *Annual Reports.*
Wanting: 1838–'44.

MICHIGAN MINERAL STATISTICS, COMMISSIONERS OF. *Annual Reports.*
Wanting: 1890, 1894, 1898, 1901, 1902-date.

MINERALOGICAL SOCIETY. *Mineralogical Magazine and Journal.*
Wanting: Vol. 1, No. 3 and Vol. 4.

El Minero Mexicano.
Wanting: Vols. 1–20, Vol. 21, Nos. 1–22; Vol. 24, No. 3; Vol. 25, Nos. 5 and 7; Vol. 26, Nos. 13 and 18; Vol. 27, Nos. 13 and 26; Vol. 30, Nos. 3–4; Vol. 33, No. 13; Vol. 35, No. 22; Vol. 37, Nos. 14 and 17; Vol. 38, Nos. 61–62; and indexes to Vols. 36, 40, 41.

Mining and Metallurgical Journal. Los Angeles, Cal.
Wanting: Vols. 1–17: Vol. 18, Nos. 1–2, 7–9.

Mining and Metallurgy, New York.
Wanting: Vols. 1–23 (all before 1903).

Mining and Scientific Press.
Wanting: Vols. 1–19 (1860–'69); 24–38, 1872–1879 (Jan.–June).

Mining and Scientific Review, Denver.
Wanting: Vols. 1–22 (1877–'88), Vol. 31, No. 26.

MINING ASSOCIATION AND INSTITUTE OF CORNWALL. *Transactions.*
Wanting: Vol. 5–date (1896–date).

Mining Engineering, London.
Wanting: Vol. 1, Nos. 1 and 18; Vol. 3, No. 66.

Mining Industry, Denver.

Wanting: Vol. 1, Nos. 1, 20, 24 and 27; Vol. 13, No. 27; Vol. 14, Nos. 23–52; Vol. 16, Nos. 1–4 and 10–52.

Mining Journal, Railway and Commercial Gazette, London.

Wanting: Vols. 1–53 and 59 (all before 1884).

Mining Magazine, New York.

Wanting: Vols. 1–3 (1853–'54); Vols. 6–8, 11–13.

Mining Reporter.

Wanting: Vols. 1–47; and Vol. 48, Nos. 1–16.

Mining Review. Continuation of Mining Industry and Review, 1898–

Wanting: Vols. 1–31 (1878–'93); Vol. 33, Nos. 1, 2, 4, 8, 11–14, and 16; Vol. 34, No. 18; Vol. 35–date.

Mining World and Engineering Record, London.

Wanting: Vols. 1–16, (1871–'79); Vols. 30–49 (1886–'95).

MINNESOTA—GEOLOGICAL AND NATURAL HISTORY SURVEY. *Annual Reports.*

Wanting: 7th, 8th and 9th.

MISSOURI—GEOLOGICAL SURVEY. *Reports of Progress.*

Wanting: 3d (1855–'56); 4th (1857–'58); 5th (1859–'60).

——— *Biennial Report of the State Geologist.*

Wanting: 1895–'96.

——— ——— *Report.*

Wanting: 10th and 12th (1896).

Modern Mexico.

Wanting: Vols. 1–6, 8–9.

MONTANA—INSPECTOR OF MINES. *Reports.*

Wanting: 6th–8th, 11th and 13th.

National Geographic Magazine.

Wanting: Vols. 1–9; Vol. 10, Nos. 1–7 and 12; Vol. 12, Nos. 9–12; Vol. 13, Nos. 2–4, 9, 11–12; Vol. 15, Nos. 5, 8–9; Vol. 16, Nos. 1–4.

Neues Jahrbuch für Mineralogie, Geognosie Geologie und Petrefaktenkunde.

Wanting: 1830–'38, 1892–date and general index.

NEVADA—STATE MINERALOGIST. *Annual Report.*

Wanting: 1865, and all later than 1866.

NEW JERSEY—GEOLOGICAL SURVEY. *Annual Report.*

Wanting: 1865–'66, and 1871.

NEW SOUTH WALES—GEOLOGICAL SURVEY BRANCH. *Records.*

Wanting: Vol. 1, Pt. 2.

NEW SOUTH WALES—MINES DEPARTMENT. *Annual Report.*

Wanting: 1880–'85.

NEW YORK ACADEMY OF SCIENCES. *Annals.*

Wanting: Vol. 11, Pts. 1–2.

——— *Transactions.*

Wanting: Index to Vol. 11.

NEW YORK STATE MUSEUM. *Bulletin.*

Wanting: Nos. 1-2, 5-6, 8-10, 40, 46-47.

NEW YORK STATE—STATE GEOLOGIST. *Annual Report of the State Geologist.*

Wanting: 1st-10th (1881-'91), 13th (1893), and 15th (1895).

NEW ZEALAND—GEOLOGICAL SURVEY. *Annual Report on the Colonial Museum and Laboratory.*

Wanting: Vols. 11, 16 and 26.

NEW ZEALAND INSTITUTE. *Transactions.*

Wanting: Vol. 2 (1869); Vols. 15-16 (1882-'83); Vols. 19-30 (1886-'97); Vol. 32 (1899).

New Zealand Mines Record, Wellington, N. Z.

Wanting: Vols. 1-6, (1896-1902).

NORTH CAROLINA—GEOLOGICAL SURVEY. *Bulletin.*

Wanting: Nos. 4-7, 12 and 14-18.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS. *Transactions.*

Wanting: Vol. 2, and Pt. 6 to end of Vol. 13, 1894.

NOVA SCOTIA—MINES DEPARTMENT. *Reports.*

Wanting: 1863 and 1898.

NOVA SCOTIAN INSTITUTE OF SCIENCE. *Proceedings and Transactions.*

Wanting: Vol. 4, Pts. 1-5; Vol. 5, Pts. 1, 4-5; Vol. 6, Pts. 1 and 5; Vol. 7, Pts. 1 and 5.

Oesterreichische Zeitschrift für Berg und Hüttenwesen.

Wanting: Vols. 1-26 (1853-'78).

OESTERREICHISCHER INGENIEUR- UND ARCHITEKTEN VEREIN. *Zeitschrift.*

Wanting: Vol. 56 (1904); Vol. 57 (1905), Nos. 1-37, and 41; Vol. 58-date, 1906-date.

OHIO—INSPECTOR OF MINES. *Annual Report.*

Wanting: Vols. 1-2, (1874-'75); 5-6, 8, 10.

Ohio Mining Journal.

Wanting: Vol. 1, Nos. 2-4; Vol. 2, Nos. 1-3 and 5-16.

OKLAHOMA—DEPARTMENT OF GEOLOGY AND NATURAL HISTORY. *Biennial Report.*

Wanting: 1st.

Ores and Metals.

Wanting: Vols. 1-12 (1892-1904), and Vol. 13, No. 19.

Pacific Coast Miner.

Wanting: Vols. 1-6.

Page's Weekly.

Wanting: Vol. 1, No. 1.

PENNSYLVANIA—GEOLOGICAL SURVEY. *Annual Report* by H. D. Rogers.

Wanting: 1st (1836), 2d (1838), 4th (1840), 5th (1841), 6th (1842).

PENNSYLVANIA—MINES DEPT. *Report of the Coal Mines Inspector.*
Wanting: 1884.

PENNSYLVANIA STATE COLLEGE. *Mining Bulletin.*
Wanting: Vol. 5, Nos. 2–end of Vol.

Petermann's Mittheilungen aus Justus Perthes' geographischer Anstalt.
Wanting: Vols. 44–date.

PHILIPPINE ISLANDS—MINING BUREAU. *Annual Report.*
Wanting: Reports 1–4.

PHILOSOPHICAL SOCIETY OF WASHINGTON. *Bulletin.*
Wanting: Vols. 1–10.

Popular Science Monthly.
Wanting: Vols. 10–21 (1876); Vol. 22, Nos. 1–2, 5; Vol. 55, Nos. 3–6; Vol. 56; Vol. 57, Nos. 1, 2; Vol. 59, No. 6; Vol. 62, Nos. 3–6; Vol. 63–date.

Practical Engineer, London.
Wanting: Vol. 3, No. 125; Vol. 4–date (1890–date).

Practical Mechanic's Journal.
Wanting: Vols. 1–5 and 8 (1848–'53); Ser. 2 (1856–'65); Ser. 3 (1865–'73).

Quarterly Journal of Science, London.
Wanting: 1864–'70, 1871, 1873–'78, 1879, 1880–'85.

Queensland Government Mining Journal.
Wanting: Vols. 1–4.

Railway and Engineering Review, Chicago.
Wanting: Vols. 1–19 (1860–'79).

Railway Reporter, Pittsburg.
Wanting: Vols. 2 and 3 (1881 and 1882).

Railway World, Philadelphia. (In which is incorporated the *United States Railroad and Mining Register.*)
Wanting: 1857–'79 and Vol. 17 (1891).

Rassegna Mineraria, Torino, Italy.
Wanting: Vols. 1–5; Vol. 6, Nos. 1–13; Vol. 7, Nos. 11, 15, 17 and 18; Vol. 8, Nos. 1–4, 6–8, 11–12 and 16; Vol. 9, Nos. 2–5; Vol. 10, No. 6; Vol. 12, Nos. 15, 17–18.

Revista del Servizio Minerario.
Wanting: 1890–'98; 1901, p. 1–368; 420–end.

Revista Minera Metalurgica y de Ingenieria, Madrid.
Wanting: Vols. 1–53 (1850–1903); (Nov.); and Vol. 54 (Jan.–Nov., 1903).

Revista Tecnologica Industrial, Barcelona.
Wanting: Years 1–11 (1878–'88); Year 12, Nos. 1–11; Year 13, Nos. 1–2; Year 15, Nos. 8–9.

La Revue Technique, Paris.
Wanting: Years 1–24; Year 25, No. 6; Year 26, No. 23–end of Vol.

Revue Universelle des Mines, etc., Liège.
Wanting: Series 1, and Vols. 1–4 of Series 2 (1857–'78); Vols. 2, 9, 11, 15, and 18 of Series 3. Table des Matières de la première et de la seconde série (1857–'76, 1877–'87).

ROYAL GEOLOGICAL SOCIETY OF CORNWALL. *Transactions.*

Wanting: Vols. 9–date (?).

ROYAL SOCIETY OF LONDON. *Philosophical Transactions.*

Wanting: Vols. 1–46; 104–112 and 167–date.

ROYAL SOCIETY OF NEW SOUTH WALES. *Journal and Proceedings.*

Wanting: Vols. 1–8.

Science.

Wanting: 1880–'94, and New Series Vols. 1–12 (1895–1900).

SMITHSONIAN INSTITUTION, WASHINGTON—U. S. NATIONAL MUSEUM. *Annual Report.*

Wanting: 1888.

——— *Proceedings.*

Wanting: Vol. 2 (1879); Vol. 4 (1881); Vol. 10 (1887); Vol. 11 (1888).

SOCIEDAD GUATEMALTECA DE CIENCIAS. *Revista Mensual.*

Wanting: Vol. 1, Nos. 1–11; Vol. 2, No. 5.

SOCIEDAD GUANAJUATENSE DE INGENIEROS. *Boletin.*

Wanting: Vol 1, No. 1; Vol. 2, Nos. 6–10; Vol. 3, No. 4–end of Vol.

SOCIEDAD NACIONAL DE MINERIA, SANTIAGO DE CHILE. *Boletin.*

Wanting: Vols. 1–7, 1882 (?)–'90.

SOCIETA TOSCANA DI SCIENZE NATURALI. *Atti, Memorie.*

Wanting: Vols. 1–2; Vol. 3, Pt. 1; Vol. 4, Pts. 1–2; Vol. 5, Pt. 1.

——— *Atti processi verbali.*

Wanting: Vol. 3 (Jan. 8, Nov. 2, 1882; Jan. 14, March 4, May 13 and July 1, 1883); Vol. 4 (Feb. 1, May 10, 1885); Vol. 5 (pp. 226–end and index 1885–'87); Vol. 6 (May 6, Nov. 11, 1888, May 12, 1889); Vol. 7 (June 6, Nov. 16, 1890); Vol. 8 (Nov. 15, 1891, Jan. 17, 1892); Vol. 10 (Nov., 1896, Jan. and July, 1897); Vol. 11; Vol. 12 (Nov. 19, 1899, Jan. 28, March 4, May 6, July 1, 1900, July 7, 1901).

SOCIÉTÉ CHIMIQUE DE PARIS. *Bulletin.*

Wanting: 1864–1904 inclusive.

SOCIÉTÉ DE L'INDUSTRIE MINÉRALE. *Bulletin.*

Wanting: Series 1, Vols. 1–15; Series 2, Vols. 1–7.

——— ——— *Atlas.*

Wanting: Pts. 2 of Vols. 11, 13, 14; also Pts. 26–33 of Vol. 2.

——— *Compte Rendu.*

Wanting: Jan. to March, 1879, and July, 1900.

SOCIÉTÉ DES INGÉNIEURS CIVILS DE FRANCE. *Annuaire.*

Wanting: 1890.

——— *Mémoires et Comptes Rendus.*

Wanting: 1848–'74; No. 6, 1877; No 3, 1878; and No. 5, 1879.

SOCIÉTÉ GÉOLOGIQUE DE BELGIQUE. *Annales.*

Wanting: Vols. 1–29, and Table de Matières.

SOCIÉTÉ GEOLOGIQUE DE FRANCE. *Bulletin.*

Wanting: Ser. 3, Vol. 3, p. 761–end of Vol.; and Vol. 9, 1880–'81.

SOCIÉTÉ GÉOLOGIQUE DU NORD. *Annales.*

Wanting: Vols. 1–7, 9–31.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION. *Proceedings.*

Wanting: Vols. 2, 3, 4 and 8.

SOCIETY OF ARTS. *Journal.*

Wanting: Vols. 1–30; Vols. 31–43; Vols. 45–51 inclusive.

SOCIETY OF CHEMICAL INDUSTRY. *Journal.*

Wanting: Vols. 1–8 (1882-'90); Vols. 10–11; Vol. 12 (Feb., 1893); Vol. 14 (Jan.-June, 1895); Vol. 15 (Nov.-Dec., 1896); and Vol. 17 (1897).

South African Engineering.

Wanting: Vols. 1–3; Vol. 4, No. 1; Vol. 5, Nos. 1 and 2.

South African Mines, Commerce and Industries.

Wanting: Vol. 1; Vol. 2, Nos. 1–93, 95, 98–99, 102–105; Vol. 3, Nos. 120 and 127.

South African Mining Journal.

Wanting: Vol. 1, Nos. 1–2, 38, 43–48; Vol. 2, Nos. 5, 16–17, 22, 25, 30, 35, 43, 46–date.

SOUTH CAROLINA—MINERALOGICAL, GEOLOGICAL AND AGRICULTURAL SURVEY. *Reports*, by Oscar M. Lieber.

Wanting: 4th Annual Report, 1859.

" Reports of the Geological and Agricultural Survey by Ruffin, 1843–'44.

SOUTH DAKOTA STATE SCHOOL OF MINES *Bulletin.*

Wanting: Nos. 1–4.

STAFFORDSHIRE IRON AND STEEL INSTITUTE. *Proceedings.*

Wanting: Vols. 1–5.

Stahl und Eisen.

Wanting: Vols. 1 and 2.

Stone.

Wanting. Vols. 1–10; Vol. 11, Nos. 1–4.

TECHNICAL SOCIETY OF THE PACIFIC COAST. *Transactions.*

Wanting: Vol. 9, Nos. 6 and 9; Vol. 10, No. 3.

TENNESSEE—GEOLOGICAL SURVEY. *Report*, by G. Troost.

Wanting: Reports 3d, 4th, 6th and 8th (1835–'47).

TEXAS—GEOLOGICAL SURVEY. *Bulletin.*

Wanting: Nos. 1 and 4.

——— *Annual Reports*, by E. T. Dumble.

Wanting: 4th Report, 1892.

TEXAS—GEOLOGICAL AND AGRICULTURAL SURVEY. *Annual Reports*, by S. B. Buckley.

Wanting: 2d (1876).

U. S. AGRICULTURE DEPARTMENT. *Annual Report.*

Wanting: 1869, 1872–'74, 1876–'77.

U. S. ARTILLERY SCHOOL. *Journal.*

Wanting: Vol. 6.

U. S. COAST AND GEODETIC SURVEY. *Annual Report.*

Wanting: 1878, and all later than 1890.

U. S. COMPTROLLER OF THE CURRENCY. *Annual Report.*
Wanting: 1885, 1887, 1889.

U. S. ENGINEERS, CORPS OF. *Annual Report.*
Wanting: 1870, 1872–'75, 1878 and 1887.

U. S. GEOGRAPHICAL AND GEOLOGICAL SURVEY OF THE ROCKY MOUNTAIN REGION. Report on the Geology and Resources of the Black Hills of South Dakota, by Henry Newton and W. P. Jenney. 1880.
Wanting: Atlas.

U. S. GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES—SECOND DIVISION. Report on the Geology of the Eastern Portion of the Uinta Mountains and a Region of Country Adjacent Thereto, by J. W. Powell. 1876.
Wanting: Atlas.

U. S. MILITARY SERVICE INSTITUTION. *Journal.*
Wanting: Vols. 1 and 9–27.

U. S. MINT BUREAU. *Annual Report* of the Director.
Wanting: 1874.

U. S. NAVAL INSTITUTE. *Proceedings.*
Wanting: Vols. 1–4.

U. S. ORDNANCE DEPARTMENT. *Annual Report* of the Chief of Ordnance.
Wanting: 1865–'72, 1874–'75, 1881, 1883–'87, 1890–'91.

U. S. ORDNANCE DEPARTMENT. *Reports of the Tests of Metals and Other Materials.*
Wanting: All before 1882.

U. S. PATENT OFFICE. *Annual Reports of the Commissioner.*
Wanting: 1850, Pt. 1, and 1869–'89.

L'UNION DES CHARBONNAGES, LIÈGE. *Bulletin.*
Wanting: Vols. 1–10 (1868–'78); Vol. 11 (1879), Pts. 1–4; Vol. 15 (1883).

Van Nostrand's Engineering Magazine.
Wanting: Vols. 12–20 (1875–'78).

VEREIN DEUTSCHER INGENIEURE. *Zeitschrift.*
Wanting: Vols. 1–21 (1857–'78).

VERMONT—GEOLOGICAL SURVEY. *Annual Reports.* (By C. B. Adams.)
Wanting: 1st, 3d and 4th.

VEREIN FÜR DIE BERGBAULICHEN INTERESSEN IM OBERBERGAMTSBEZIRK DORTMUND. *Jahresbericht.*
Wanting: 1896, and statistical part of 1901.

WEST VIRGINIA—MINE INSPECTOR. *Annual Report on Coal Mines.*
Wanting: 2d, 5th, 7th and 8th.

WESTERN AUSTRALIA—GEOLOGICAL SURVEY. *Bulletin.*
Wanting: No. 2.

Western Mining World. (Continued as Mining World from Vol. 19, 1903.)

Wanting: Vol. 4, Nos. 1–81 (1896); Vol. 5, No. 116 (1896); Vol. 7, Nos. 146, 253 (1897); Vol. 11, No. 253 (1899); Vol. 13, Nos 21 and 25 (1900); Vol. 14, No. 13 (1901); Vol. 16, Nos. 8–10 (1902); Vol. 18, No. 22 (1903).

WISCONSIN—COMMISSIONER OF THE SURVEY OF THE LEAD DISTRICT.

Wanting: Report of the Geological Survey of the Mineral Regions, by Murrish, 1872.

WISCONSIN—GEOLOGICAL SURVEY.

Wanting: 1858 (title reads, Reports of the Commissioners of the Geological Survey).
" 1860 (title reads, Report of the Superintendent of the Geological Survey).

Zeitschrift des Architekten und Ingenieur-Vereins für das Königreich, Hannover.

Wanting: Vols. 1–15: Vol. 16, Pt. 4; Vols. 17–47.

Zeitschrift DES OBERSCHLESISCHEN BERG U. HÜTTENMÂNENNISCHEN VEREINS.

Wanting: 1862–'91, 1892–1903.

Zeitschrift für Angewandte Chemie.

Wanting: Vols. 1–11 (1887–'99); Vols. 15–17 (1903–'04).

Zeitschrift für Anorganische Chemie.

Wanting: Vols. 1–38 [1892–1903).

Zeitschrift für Bergrecht.

Wanting: Vols. 1–13, 16–41.

Accessions.

From September 11 to November 8, 1906.

James Ashworth.

ASHWORTH, JAMES. *Safety Lamp Gauzes and Flame Tests for Firedamp.* 4to, 11 p. il. n. p. n. d.

Professor W. P. Blake.

U. S. ENGINEERS, CORPS OF. *Annual Report*, 1868, 1876–'77, 1881–'86, 1888–'89. 8vo, Washington, 1869, 1876–'89.

G. W. Colles.

COLLES, G. W. *Mica and the Mica Industry*, vi, 130 p. il. pl., 8vo, Philadelphia, 1906. Price, $2.00.

[SECRETARY'S NOTE.—This monograph is the result of the enlargement and revision of a paper presented before the Chemical Section, and published in the *Journal of the Franklin Institute.* It discusses the mineralogy of mica, the geology of the granitic and pyroxenic groups, their geographical distribution, the history

and methods of their exploitation, the uses of mica, and the statistics of its production, etc. An alphabetic index completes its value for reference —R. W. R.]

Dr. James Douglas.

Address of Mr. Holt S. Hallett, upon Burmah, 20 p., 8vo, London, 1887.

American Chemical Journal. Vols. 1–6, 8vo, Baltimore, 1879–'85.

AMERICAN CHEMICAL SOCIETY. *Journal*, vols. 1–2, 8vo, New York, 1879–'80.

——— *Proceedings*, vols. 1–2, 8vo, New York, 1878.

CIENEGUITA COPPER COMPANY. *Prospectus*, 1901.

MINNESOTA—GEOLOGICAL AND NATURAL HISTORY SURVEY. *Annual Report*, 1, ed. 2, 8vo, Minneapolis, 1884.

WINCHELL, A. *Ignatius Donnelly's Comet*, p. 105–115, 8vo, n. p., n. d.

SOCIETY OF ARTS. *Journal*, vol. 31, 1883, pp. 205–936; vol. 33, 1885, pp. 949–960, 971–1151; vol. 34, 1885–86, pp. 55–76, 95–354, 395–986, 1007–1311; vol. 35, 1886–87, pp. 1–518, 537–1015; vol. 36, 1887–88, pp. 1–400, 431–482, 525–720, 751–906, 931–1190; vol. 37, 1888–89, pp. 1–194, 213–532, 559–652, 663–924; vol. 38, 1889–90, pp. 1–304, 335–688, 705–828. 877–1036, 1053–1070; vol. 39, 1890–91, pp. 1–50, 65–834, 847–914, 935–948; vol. 40, 1891–92, pp. 1–610, 645–736, 753–1055; vol. 41, 1892–93, pp. 1–88, 101–112, 125–360, 393–684, 705–992, 1005–1042; vol. 42, 1893–94, pp. 1–80, 93–392, 409–904, 917–959; vol. 43, 1894–95, pp. 1–146, 167–1008; vol. 44; vol. 45, 1896–97, pp. 1–56, 77–262, 289–602, 631–1078, 1091–1203; vol. 46, 1897–98, pp. 1–568, 617–648, 665–704, 745–872, 885–946; vol. 47, 1898–99, pp. 1–172, 209–530, 563–594, 611–627; vol. 48, 1899–1900, pp. 21–40, 273–756, 781–902; vol. 49, 1900–1, pp. 1–16, 29–44, 57–152, 181–232, 269–700, 713–748, 773–784, 797–808, 821–832; vol. 50, 1901–1902, pp. 1–92, 105–504, 533–616, 633–943; vol. 51, 1902–03, pp. 23–38, 73–388, 423–462, 489–578, 593–636, 647–708, 769–784, 799–962; vol. 52, 1903–04, pp. 1–198, 247–700, 721–794, 809–842, 853–862, 873–898; vol. 53, 1904, pp. 1–18, 37–106. *Index to vols.* 1 10.

J. P. Gibson, Hexham, England.

An Account of the Roman Antiquities Preserved in the Museum at Chesters, Northumberland, xvi, 432 p., il. 8vo, London, 1903.

W. & L. E. Gurley.

GURLEY, W. & L. E. *A Manual of Instruments Used in American Engineering and Surveying*, ed. 39, 446 p., il. per 16mo, Troy, 1905.

Professor Hans Höfer.

HÖFER, HANS. *Das Erdöl*, xvii, 279 p. il. pl. 8vo, Braunschweig, 1906.

George Iles.

ILES, GEORGE. *Inventors at Work, with Chapters on Discovery*, xxii, 503 p. il. 8vo, New York, 1906. Price, $2.50.

[SECRETARY'S NOTE.—This book is a suggestive survey of modern inventions, which it describes in language of scientific accuracy, yet of picturesque and popular charm—a combination not easy to achieve. The author classifies modern inventions under improvements in form (under which he treats of the proper distribution of material in rails, bridges, etc., the designs of ships, lenses, and various tools and machinery); improvements in size (involving a discussion of the economy of large constructions and operations); improvements in the utilization of well-known or newly-discovered properties of materials (covering the modern appliances for light, the latest applications of steel and other alloys, the uses of sodium, etc.); and improvements in the measurement of dimensions, weight, time, heat, and electricity. A number of fascinating chapters, biographical, philosophical and speculative, complete this suggestive survey of the modern advances in science and its applications.—R. W. R.]

W. R. Ingalls.

CANADA—DEPARTMENT OF THE INTERIOR. *Report of the Commission Appointed to Investigate the Zinc Resources of British Columbia and the Conditions Affecting their Exploitation*, xvii, 399 p. 8vo, Ottawa, 1906.

INGALLS, W. R. *Notes on Metallurgical Mill-Construction*, vii, 256 p., il. pl. 8vo, New York, 1906. Price, $2.00.

[SECRETARY'S NOTE.—This is a reprint of important articles by various authors which have appeared in the *Engineering and Mining Journal* (with one from the *Pacific Coast Miner*). Many of them were abstracts of papers in the *Transactions* of the American Institute of Mining Engineers, and other technical societies. Mr. Ingalls frankly declares the miscellaneous and fragmentary character of the book, and offers it "simply as a series of notes and essays, covering some of the principal subjects upon which the engineers of four continents have written during the past three years." The subjects treated are classified under "Ore-Crushing Machinery," "Driers and Drying," "Conveyors and Elevators," "Disposal of Tailings," and "Miscellaneous."—R. W. R.]

Kaiserliches Patentamt.

Germany — Kaiserliches Patentamt. *Repertorium der Technischen Journal-Literatur*, 1905. 4to, Berlin, 1906.

W. F. Kirk.

American Manufacturer and Iron World, Vol. 44, No. 18 (May 3, 1889); Vol. 64, No. 18 (May 5, 1899); Vol. 66, No. 4 (Jan. 25, 1900); Vol. 67, Nos. 4 and 6 (July 26 and August 9, 1900).

Mining Reporter.

Underhill, James. *Mineral Land Surveying*, 4, 1, 218 p. il. pl., 8vo., Denver, 1906. Price, $3.00.

[Secretary's Note.—This pocket hand book of 218 pages gives a clear account, with illustrative diagrams and examples, of the methods now used in surveying mineral lands in the Western United States. It presupposes a general knowledge of instruments and ordinary field-work, and constitutes a convenient appendix to the ordinary manual. The survey of mineral lands is peculiar in two respects: (1) it is not always checked by pre-existing boundaries and monuments, or by the lines of public or cadastral maps, and hence calls for a high degree of independent accuracy; and (2) the consequences of error are specially serious, because of the possible large value of a small area of mineral land. This treatise describes in successive chapters Direct Solar Observations, Solar Attachments, Measurements, Location Surveys, Patent Surveys, Patent Field-Notes, Law Office Regulations and Records, etc. The final chapter gives the nature of the examination which the candidate for a commission as U. S. Deputy Mineral Surveyor must pass. Dr. Underhill acknowledges assistance received in its preparation from many well-known surveyors and instructors.—R. W. R.]

R. W. Raymond.

Bullock, W. S. *Cobalt and its Silver Mines*, 87 p., 8vo, New York, 1906. Price, .25.

Heinrich Ries.

Ries, Heinrich. *Clays, Their Occurrence, Properties and Uses*, xvi, 490 pp. il. 8vo, New York, 1906. Price, $5.00 net.

[Secretary's Note.—Prof. Ries is already known as an original investigator in this field, and his own work has necessarily made him acquainted with the work of others, and qualified him to record, classify and estimate it with judgment. The literature of the subject is enormous, and of unequal value. Such a guide as this summary offers will be valuable to practicing engineers, as well as to students. The book treats successively of the origin, chemical and physical properties, and classification of clays; the methods of mining and manufacture; and the distribution of clay-deposits and industries in the United States. A final chapter is devoted specially to fuller's earth. The book is profusely illustrated, and furnished with numerous and accurate references to original authorities, and a good alphabetical index, as well as a full table of contents.—R. W. R.]

J. O. E. Trotz.

Jern Kontorets Annaler, vols. 3, 5–11, 14–15, 8vo, Stockholm, 1819, 1821–1832.

D. Van Nostrand Company.

PRELINI, CHARLES. *Earth and Rock Excavation*, ed. 2 rev. vi, 357 p. il. 8vo, New York, 1906. Price, $3.00 net.

[SECRETARY'S NOTE.—The importance of this subject is so great as to cause some surprise that engineering literature presents so few comprehensive discussions of it. This book begins with the graphic representation and calculation of earth-work, after which follow chapters describing the processes of excavation by hand, the use of explosives and the construction and operation of machines used in the excavation and transportation, including aerial ways, cable-ways, telpherage, etc. Practical suggestions as to animal and mechanical labor, the direction of excavation work, the shrinkage of earth and the cost of earth-work are given in succeeding chapters; and the volume ends with a compilation of interesting examples of large canal-excavations. It is handsomely printed and illustrated, and should prove valuable to many old engineers, as well as to the younger ones for whom it is primarily intended.—R. W. R.]

Victoria Public Library, Museums and National Gallery.

ARMSTRONG, E. la T. *Book of the Public Library, Museums and National Gallery of Victoria*, 1856–1906, 4, 135 p., per pl., 8vo, Melbourne, 1906.

John Wiley and Sons.

MILLER, A. S. *The Cyanide Process*, viii, 95 p. il. 12mo, New York, 1906. Price, $1.00.

[SECRETARY'S NOTE.—The first edition of this little manual was issued in 1903, primarily for the use of Prof. Miller's own students. Its brevity, simplicity and convenient form brought it into wider circulation among practitioners; and the resulting demand for it has led to the publication of this second (revised and enlarged) edition. While it cannot take the place of more elaborate and profound treatises, it fills very usefully a place of its own, and deserves to be popular.—R. W. R.]

Wilson-Snyder Manufacturing Company.

WILSON-SNYDER MANUFACTURING COMPANY. *Catalogue of Pumping Machinery*, 144 p. ob. 16mo, Pittsburg, 1906.

PURCHASES.

ENGINEERING AND MINING JOURNAL. *Mineral Industry*, vol. 14, 8vo, New York, 1906.

STEVENS, HORACE. *Copper Handbook*, vol. 6, 8vo, Houghton, 1906.

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SECTION II.

TECHNICAL PAPERS AND DISCUSSIONS.

[The American Institute of Mining Engineers does not assume responsibility for any statement of fact or opinion advanced in its papers or discussions.]

A detailed list of the papers contained in this section is given in the Table of Contents, pages i and ii.

Comments or criticisms upon all papers given in this section, whether private corrections of typographical or other errors or communications for publication as "Discussions," or independent papers on the same or a related subject, are earnestly invited.

ERRATA.

Corrections to *Bi-Monthly Bulletin*, No. 11, September, 1906.

Page.	Line.	
632	26	For "ignot" read "ingot."
633	2	For "was" read "were."
636	39	For "all" read "none of."
647	23	For "is" read "are."
648	2	For "is" read "are."
650	22	For "two every 200" read "two for every 200."
666	2	For "every other" read "every alternate."
667	17	For "will" read "shall."
727	10	For "Fe_3 C Fe +" read "Fe_3 C + Fe."

sop, William, & Sons, Ltd., Sheffield; Lanarkshire Steel Co., Ltd., Motherwell; Lilleshall Co., Ltd., Shifnal; Linthorpe-Dinsdale Smelting Co., Ltd., Middlesbrough; Lloyd, F. H., & Co., Ltd., Wednesbury; Macfadyen, P., & Co., London; MacLellan, P. & W., Ltd., Glasgow; Mason, Adam, & Sons, Bolton; Mining Institute of Scotland, Hamilton; Moss Bay Hematite Iron & Steel Co., Ltd., Workington; Müller, W. H., & Co., Rotterdam; Naylor, Benzon & Co., Ltd., London; Normanby Iron Works Co., Ltd., Middlesbrough; North-Eastern Railway Company; North-Eastern Steel Co., Ltd., Middlesbrough; North of England Institute of Mining Engineers; Oakes, James, & Co., Alfreton, Otis Steel Co., Ltd., London; Park Gate Iron & Steel Co., Ltd., Rotherham; Pearson & Knowles Coal & Iron Co., Ltd., Warrington; Pease & Partners, Ltd., Darlington; Pickerings, Ltd., Stockton-on-Tees; Raine & Co., Ltd., Newcastle-upon-Tyne; Richardson, Duck & Co., Stockton-on-Tees; Richardsons, Westgarth & Co., Ltd., Middlesbrough; Richmond Iron & Steel Co., Stockton-on-Tees; Ridley, T. D., & Sons, Middlesbrough; Ritchie, J. & R., Ltd., Middlesbrough; Samuelson, Sir B., & Co., Ltd., Middlesbrough; Sankey, Joseph, & Son, Ltd., Bilston; Scott, Walter, Ltd., Leeds; Seaton Carew Iron Co., Ltd., Seaton Carew; Seebohm & Dieckstahl, Ltd., Sheffield; Senior, George, & Sons, Ltd., Sheffield; Shaw, W., & Co., Middlesbrough; Simon-Carves Bye-Product Coke Oven Construction & Working Co., Ltd., Manchester; Simpson, James, & Co., Ltd., London; Skinningrove Iron Co., Ltd., Skinningrove, Carlin How, S. O.; Slag Reduction Co., Ltd., London; Smith, Frederick, & Co., Ltd., Halifax and Manchester; Somers, Walter, & Co., Ltd., Halesowen; South Durham Steel & Iron Co., Ltd., Stockton-on-Tees; Spencer, John, Ltd., Coatbridge; Steel Company of Scotland, Ltd., Glasgow; Steel, Peech & Tozer, Ltd., Sheffield; Stein, John G., & Co., Ltd., Bonnybridge; Summers, John, & Sons, Ltd., Stalybridge; Swan Brothers, Middlesbrough; Talbot Continuous Steel Process, Ltd., Middlesbrough; Teesside Bridge & Engineering Works, Ltd., Middlesbrough; Thomas, R., & Co., Ltd., Llanelly; Thornycroft, John I., & Co., Ltd., Chiswick; United States Steel Products Export Co., London; Vickers, Sons & Maxim, Ltd., Sheffield; Ward, Thos. W., Ltd., Sheffield; Warren, Beattie & Co., Ltd., Middlesbrough; Watson, James, & Co, Middlesbrough; Watson, W. J., & Co., Middlesbrough; Waverley Iron & Steel Co., Ltd., Coatbridge; West of Scotland Iron & Steel Institute, Glasgow; Whitehead, L. D., & Co., Tredegar; Whitwell, W., & Co., Ltd., Stockton-on-Tees; Wigan Coal & Iron Co., Ltd., Wigan; Williamson, R., & Son, Workington; Wilsons, Pease & Co., Ltd., Middlesbrough; Wood, John, & Sons, Ltd., Wigan; Worthington Pump Co., Ltd., London.

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The Right Honorable The Lord Mayor of London (Alderman Sir W. Vaughan Morgan, Bart.) (*President*), R. A. Hadfield (*Chairman*), Sir W. Lloyd Wise (*Vice-Chairman*), Bennett H. Brough (*Secretary*), Professor H. Bauerman, P. B. Brown, Professor W. Gowland, F. W. Harbord, A. C. Meyjes, Matthew Murray, L. Pendred, Septimus Young.

Tees-Side Reception Committee.

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Ladies' Committee.

Lady Bell, Lady Ropner, Lady Sadler, Lady Wrightson, Mrs. John H. Amos, Mrs. Arthur Cooper, Mrs. A. J. Dorman, Mrs. John Hedley, Mrs. James Riley, Mrs. J. E. Stead, Mrs. T. Westgarth, Mrs. Illtyd Williams, Miss Hedley, Miss Gilzean Reid, Miss Whitwell.

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Newcastle-upon-Tyne Reception Committee.

The Right Honorable The Lord Mayor of Newcastle-upon-Tyne (Alderman Sir J. Baxter Ellis), The Sheriff of Newcastle-upon-Tyne (Councillor Johnstone Wallace), President of the North of England Institute of Mining and Mechanical Engineers (T. W. Benson), Charles A. Harrison, C. S. Swan, John Tweedy, Ivan C. Barling, T. E. Foster, M. W. Parrington, J. J. Prest, F. R. Simpson, Right Honorable Lord Armstrong, J. P. Gibson.

Glasgow Reception Committee.

(The West of Scotland Mining Institute and the Mining Institute of Scotland), A. Lamberton (*Chairman*), Andrew Campion (*Secretary*), Robert T. Moore, J. G. Jenkins, W. Clark, T. B. Rogerson, Walter Dixon, G. A. Mitchell, J. T. Forgie, H. D. D. Barman, R. D. Munro.

Edinburgh Reception Committee.

John Cowan (*Chairman*).

Stewards of the Provincial Tour.

Professor H. Bauerman, W. F. Cheesewright (and Mrs. Cheesewright), D. A. Louis, A. C. Meyjes, L. Pendred (and Mrs. Pendred), Hubert S. Thomas (and Mrs. Thomas).

This joint meeting originated in a cordial invitation extended by the Council of the Iron and Steel Institute, and accepted with enthusiasm by the Council of the American Institute of Mining Engineers. Earnest invitations were afterwards received from other societies; and the Institution of Civil Engineers, the Institution of Mining and Metallurgy, the North of England Institute of Mining and Mechanical Engineers, the West of Scotland Iron and Steel Institute and the Mining Institute of Scotland co-operated heartily in the programme of the Iron and Steel Institute, as the following pages will show. Moreover, the Institute of Mechanical Engineers entertained a considerable number of guests at its meeting held July 31–August 3, at Cardiff, Wales. And finally, the Society of German Ironmasters organized and conducted a supplementary visit to Germany.

Under a mutual agreement between the Councils of the American Institute of Mining Engineers and the Iron and Steel Institute, it was decided to hold three sessions at this meeting: the first to be a session of the Iron and Steel Institute, the second, a session of the American Institute of Mining Engineers, and the third, a joint session of both Institutes.

This agreement provided further that each of the two societies should be free to publish such papers and discussions, presented at either of the sessions, as it should deem desirable. In accordance with this understanding, certain papers presented to the Iron and Steel Institute will be published in the *Bi-Monthly Bulletin* of this Institute; and some of the most important will be also included in the next volume of the *Transactions*, if space can be found for them. For the text of papers not thus reprinted by this Institute, members are referred to the *Journal of the Iron and Steel Institute.*

The first session, being a session of the Iron and Steel Institute, was held in the Hall of the Institution of Civil Engineers, 12 Great George Street, Tuesday, July 24, at 10 a.m., President Hadfield presiding.

The minutes of the meeting of the Iron and Steel Institute, held in May, 1906, were read by the Secretary, Mr. Bennett H. Brough, and duly passed.

The following address of welcome was delivered by Mr. Hadfield:

PRESIDENT HADFIELD'S ADDRESS.

In offering this morning a most hearty and cordial welcome to you, the members of the American Institute of Mining Engineers, I know that every one in this country interested in iron and steel joins with me. We feel the greatest satisfaction that so many of our friends from America have been able to come to this important international meeting held in our great metropolis.

Devoted as those present are to the study of the metal iron, we cannot forget the deep significance of the metallurgists of two great industrial Powers—mother and daughter—drawing together in mutual respect. Such gatherings are of the utmost international importance, and not only as President of this Institute, but as an Englishman, I again offer you the heartiest and most cordial welcome to our country. May each of our great nations increase in prosperity and help on the cause of peaceful progress and freedom, dear alike to the hearts of Englishmen and Americans of whatever rank and in whatever walk of life.

In this little island we cannot show you vast distances, but we hope we can interest you in our historical remains. Descended as we are from practically one common stock, they are yours as well as ours. We hope, too, that what we show you on the technical side will prove that we are not standing still. If our efforts to make your stay pleasant earn your approval, we shall be more than satisfied.

We shall do our best to try to return in the short time you are with us some of that magnificent hospitality we experienced at your hands in those memorable gatherings of 1890 and 1904. You have set us a great example; and whilst we should have been delighted to surpass you, that is impossible, but we can offer you an equally hearty welcome. I venture to think that these visits help not a little in bringing England and America more closely together—two nations which, though divided by great distance, are more closely allied in origin, thought, laws, and literature than any others. May their future for all time be bound together in the paths of peace and progress!

The good feeling between England and America grows stronger each year; and has not one of your famous men who

managed an army of over a million soldiers said if ever there was a "shindy" on this side of the water, America would not sit by, but would come over and help us? When General Sherman expressed this sentiment, he added: "I feel no difference in this hall between an assembly of Englishmen and Americans." This was at our New York meeting, held fifteen years ago, and the remark comes back to us with still greater force to-day.

In the arrangements made for your comfort and pleasure, not the least of the difficulties we have had to face has been that of selecting from the numerous offers of help. Besides the visits here and around London, we have been able to arrange tours to the North of England and the manufacturing districts of Scotland. In each of these centers an able and hard-working committee will carry out important programmes. The excellent work done by the Tees-Side and West of Scotland committees, headed respectively by Sir Hugh Bell and Mr. Lamberton as chairmen, aided by their energetic colleagues, augurs well for the manner in which you, our visitors, will be received in your northern tour. Visits have also been arranged in London to places of antiquarian interest, cathedrals, castles, Roman remains, and to some of the halls of the great City Guilds, with their treasures dating back to mediæval times. As an indication of the enthusiasm with which the arrangements for your reception have been received, it may be stated that since March no fewer than five thousand letters bearing upon the meeting have been dealt with by our Secretary, Mr. Brough.

Some Personal References.

I take this opportunity of saying how much indebted the Institute is to Mr. Brough, not only for the exceedingly able manner in which he has managed the arrangements, but also for the way in which he has regarded the whole visit as not merely routine work, but as a labor of love.

The Executive Committee has also rendered most willing service; and the suggestions received from Sir James Kitson, Sir Hugh Bell, Messrs. Windsor Richards, and Martin have been invaluable. Further, the members of the Reception Committee, with the Lord Mayor of London at their head, have enthusiastically thrown their whole energies into the organizing work

where details have had to be dealt with. I should not like to close these remarks without expressing our indebtedness, and more than ordinary thanks, to the Lord Mayor (Sir Walter Vaughan Morgan), as also to Sir William Lloyd Wise, Professors Bauerman, Gowland and Harbord, and Messrs. Meyjes, Murray, Pendred, Young and Brown.

Although, greatly to my personal regret, I was unable to be present on the second visit of this Institute to your country, I shall never forget the hospitality you showered upon us in 1890, and how willingly the hand of friendship was held out to us on every occasion. I had then one of the most delightful times of my life, seeing your wonderful continent, traveling from great New York to staid Philadelphia, to busy Pittsburg and Chicago, then far west into the mountain fastnesses of Colorado; later, too, those wonderful works of nature, the Yosemite and the Yellowstone regions. Everywhere, on every hand and occasion, nothing but the most cordial hospitality was met with.

This Institute has of late sustained great losses, and we know you will join with us in mourning the absence of those bearing such household names in metallurgy as Sir Lowthian Bell—concerning whom Professor Howe's biographical masterpiece demands our grateful thanks; Sir Bernhard Samuelson, Sir Edward Carbutt, Sir David Dale, and Mr. Snelus.

You will, on the other hand, share the satisfaction of knowing that we have with us the father of our Institute, Sir John Alleyne, also Mr. J. D. Ellis, who is now over eighty-four years of age, and Sir James Kitson, who so worthily sustained the dignity of his country and the renown of this cosmopolitan Institute during those memorable trips of 1890 and 1904. You, yourselves, have reason to be proud in still having with you Mr. John Fritz, the Nestor of the American iron trade, now, I believe, within a month of completing his eighty-fourth year; we greatly regret he cannot be with us to-day. As he is one of our Bessemer medalists and honorary members, I suggest we send to him this cablegram, in united friendly greeting:

"This great and memorable gathering of Englishmen and Americans united send you, Bessemer medalist and honorary member of the Iron and Steel Institute, heartiest and most friendly greetings. We congratulate you upon the im-

mense progress in metallurgy made during your lifetime, in which you have played so honorable a part. Long may you be spared to us."

I will conclude these personal references by saying how much this Institute has been indebted to our late President, Mr. Andrew Carnegie, who, notwithstanding rumors to the contrary, is still on the sunny side of seventy. We are delighted to have had him as our President, and we are proud that he, an American, occupied the presidential chair, the first not a British citizen to do so. In a personal letter to myself he writes:

"It is a matter of deep disappointment and regret that I am prevented from joining you in London, and doing what I could, if anything, to aid and support you in your duties. That you will all render memorable the forthcoming visit of the American societies I feel confident. It would have been a great pleasure to me to appear in my international capacity of British-American, taking each of the two sections by the hand and joining them together in bonds of lasting friendship.

"With every good wish for one and all."

Metallurgy must ever be indebted to America as a country which has produced such men as Fritz, Hewitt, Holley, Jones, Howe, Langley, Metcalfe, Sauveur, Campbell, Dudley, Gayley, and, finally, your President, Mr. Robert W. Hunt, and your Secretary, Dr. Raymond. Further, your wonderful technical press, which ransacks the world for information, is but another proof of your untiring energy and indomitable perseverance on behalf of the cause in which we are interested.

The San Francisco Disaster.

I would here say a few words with regard to the terrible calamity one of the most beautiful of your cities has recently sustained. The monetary loss alone is estimated to have been $75,000,000, and this is a minimum figure. Never did a greater wave of sympathy run through Great Britain and Ireland—and indeed the whole of our vast dominions throughout the world—than when the news came of the terrible disaster at San Francisco. Her citizens have risen nobly to a situation almost unparalleled in history. We congratulate you; and may we not also congratulate ourselves on this further proof of the Anglo-Saxon being able to surmount any difficulties it may be his lot to meet in this mundane sphere? I am express-

ing the feelings, not only of every member of our Institute, but of every Englishman, when I say that we wish San Francisco not only freedom from those terrible visitations of earthquakes, but that she may arise literally from her ashes stronger and more powerful than ever before.

I do not know whether all present have seen that remarkable photograph of the Kohl building in San Francisco, representing one of the few structures which were not destroyed by either shock or fire. There it stands, tall and unscathed, in the midst of a scene of terrible devastation, the American flag flying proudly from its garden roof, as if to show the world that the citizens of San Francisco were undaunted, even though they had passed through one of the greatest disasters of modern times. All honor to a country which has produced such a city and such citizens!

Happily, the increasingly important position occupied in the world's progress by technical men is being recognized, and I venture to say that not least among them is the metallurgist. To those assembled here may I say that, for the first time in the world's history, the importance of the science in which we are interested—namely, metallurgy—has this year been recognized from the academic point of view, for the University of Sheffield, under its newly-formed charter, now confers the degrees of Doctor, Master, and Bachelor of Metallurgy.

Industrial Progress.

On an occasion like this one cannot but draw some comparisons between the present time and the time when we first visited you. In 1890 America had commenced to pass us in its production of pig-iron, making what must seem now the modest total of about 9,000,000 tons, we having made 8,000,000 tons. American imports and exports were then valued at about £300,000,000, against our £684,000,000. To-day your production of pig-iron has increased to the enormous figure of about 23,000,000 tons. You almost startle us with your proposals for the Gary plant, an expenditure of over £15,000,000, and 60- to 80-ton basic open-hearth furnaces. I, for one, congratulate you most heartily, as in the advancement and prosperity of one country the world generally must benefit. In this expression of opinion English members of the Institute will spe-

cially join me, as they know much of this remarkable progress has been brought about by members of your Institute.

We, in our turn, have prospered not a little: for if this year our trade returns continue to expand, or even remain on the same footing as for the first six months, it is probable that the total trade of this country, imports and exports, will amount in 1906 to the gigantic total of not far short of £1,000,000,000 sterling, or, to express it "Americanly," $5,000,000,000. If our colonial and foreign exports, which are, of course, valuable and profitable, are included, our grand total should be nearly £1,100,000,000 sterling.

If exports represent the desideratum in the iron and steel trade, then, as that excellent American technical paper, the *Iron Age*, points out, in the first four months of 1906, as compared with 1905, Great Britain's exports of iron and steel have been considerably more than those of the United States and Germany put together.

In face of these enormous figures on every hand, one can but speculate upon the future. Prophesying before you know is always dangerous, notwithstanding Benner's remarkable record; but there is no doubt that, in the not-far-distant future, unless some very important source of iron-ore is discovered, we shall have to husband our ore supplies, or iron may some day be as dear as, for example, copper.

In my presidential address last year, I indicated that it was probable that by the year 1950 there would be produced annually 100,000,000 tons of pig-iron, so that, as compared with 1800, when only about 5,000,000 tons were used, at least 300,000,000 tons of ore would be wanted annually. According to trustworthy authorities, only about 10,000,000,000 tons of iron-ore are available in known workable iron-fields, yet by the end of the twentieth century a grand total consumption of probably 45,000,000,000 tons of ore will have been called for. Whence are the supplies to come?

If this probable serious position of affairs is applied practically to ourselves of to-day, we realize that the man who makes 1 lb. of iron go as far as 2 lb. now do, is a public benefactor of the highest order.

The world's production of pig-iron has doubled in the short space of fifteen years—that is to say, it has advanced from

27,000,000 tons in 1890 to 54,000,000 tons in 1905, approximately of the value of £160,000,000. We regard the production of gold as enormously important, yet the total value of the whole of this precious metal produced in the world last year—and it is well known—only amounted to £77,000,000.

Such colossal outputs of iron and steel demand colossal organizations; and therefore it is natural to find that you have now a company in America—the United States Steel Corporation—which has on its pay-roll nearly 200,000 employees, its distribution annually in wages being a sum approximating £30,000,000. But what is this in a country which has more than 200,000 miles of railways and 150,000 locomotives?

Congratulations.

We offer our congratulations upon the successful inauguration of the Engineering Building in New York, which is to bring together the whole of the technical bodies of the United States of America. Such a palatial home excites our admiration, and we remember that it has been made possible by the munificent help of one who has also done much for us. Although all do not agree upon the point, surely the bringing together of the various technical institutes under one roof should prove of great value. The saving in time alone must be considerable, to say nothing of other advantages. We wish the construction may soon be brought to a happy conclusion, and that the success attending its use will amply reward the donor.

As we also are interested in the advance of metallurgy upon true scientific lines, we offer our best wishes on the opening of the new building devoted to this science in the Columbia University, the gift of Mr. Lewisohn. Not one of the least objects of interest there, to those who knew his worth, will be the bronze bust of Professor Egleston, who founded the School of Mines in 1865.

We congratulate you on having brought over as your President such an excellent representative of the prowess of metallurgy as Captain Hunt, whose work on its behalf has been invaluable; and not less upon the presence still in your councils of Dr. Raymond, a host in himself. Never can we on this side forget his cordiality to us, not only during our official ex-

cursions, but also when we have exchanged those friendly private visits that are happily becoming more and more frequent between us.

Finally, may I hope that this visit will be a record one in every way; one that will ever remain in your minds, and cause you to say in after-times that the Iron and Steel Institute indeed did its best to show, not only hospitality, but that spirit of personal friendliness which, like the faith that could move mountains, is the true spirit which tends towards the permanent progress of the world!

Sir James Kitson, past-President of the Iron and Steel Institute, welcomed the American Institute substantially as follows:

Greetings from Sir James Kitson.

If you look at this little programme which you have in your hands, you will see that I have the melancholy distinction of being the senior past-President of this Institute. Since our last meeting with our American friends in New York, one of our distinguished Presidents, Sir Lowthian Bell, long the chief supporter of this Institute at all its meetings, has been succeeded, as I am glad to think he has, by his talented son, whose services we hope to utilize for the advantage of the Institute; and the disappearance of Sir Bernhard Samuelson, Sir David Dale and others, leaves me in the position which, may I say, I shall hope long to enjoy, of being the senior past-President, and, therefore, it is fitting that I should just add one word to those eloquent periods of your President in welcoming our American friends to England. I remember in our great visit of 1890 to the States, when I had the honor of being the President, and of leading a magnificent body of English iron manufacturers and engineers, that in New York I was referred to by Mr. Abram Hewitt as the representative of a fossil manufacture. The fossil manufacture he referred to was that of best Yorkshire iron, and he said that it might be found here and there in the hands of engineers as a curious relic of high quality, and the rest. Well, I venture to say that we are still going strong, but how strong I leave you to judge by the sample which is before you. But when you come here to see our fossils and our remains, you will find that the iron and steel

trade, also like the sample, is still going strong in the old country; and although we cannot rival those colossal figures which you are able to give us, yet we are able to say that Great Britain at this moment is manufacturing more iron and steel, is producing more coal and using it for the purposes of industry than she has ever done in the history of the world. That is something for a fossil to be able to say. But you Americans, when you come over to our country, are in the habit of saying, "Shakespeare is not yours, Shakespeare is ours; he is a man of the Anglo-Saxon race." You are in the habit of saying, as many American friends have said to me, "Your Westminster Abbey and your great ruins are not yours; they are ours; they are enjoyed by the whole Anglo-Saxon race." Well, when you come here to-day, let me say that these great works of ours, and these great objects that we are going to show you, are, at any rate for the day, and the week, and the month, not ours, but they are yours. You are entering upon your own domain of enjoyment and possession, and all that we can do shall be done to make your stay a happy and, I hope, a useful one.

President Hadfield then called on Captain Hunt, the President of the American Institute of Mining Engineers, and suggested that he be received in true English fashion, with "Kentish fire."

PRESIDENT HUNT'S ADDRESS.

I have lived a long time, but during all those years I think I may say I have never been placed in quite so embarrassing a position as this, of being placed under "Kentish fire." Claiming, and being proud of the fact, that my ancestors came from England, I must search and see if I cannot locate them as belonging to the county of Kent. Certainly, Mr. President, your comprehensive and eloquent address is one which will be appreciated by us all, and we only wish that we could feel worthy of it and of the flattering things which you have said. Undoubtedly, sir, the touching and affectionate allusions that you have made to those of our members whom we venerate with you please us and touch us most deeply; and I know that dear old man, Uncle John Fritz, will spend one of the happiest days of his life when he receives that cablegram to which you referred. Regarding the round of visits that have been arranged for us,

if some of us should say things that might seem to you better left unsaid, or may appear to be somewhat of an elevated character, bear with us, and appreciate that living in a country of those great distances to which you, Mr. President, have referred, it is almost an impossibility for us to contract our statements. But no matter to what extent we go in our expression of thanks to you, the words will not be big enough or strong enough to express all that we owe you for this magnificent reception, and the warm hospitality which we are now enjoying. If the American Institute of Mining Engineers ever had happy days, those must be regarded as such when they had an opportunity of welcoming you and your organization to America. In fact, we almost feel that we are a part of the Iron and Steel Institute. Unquestionably, it was the success of your society which led to the organization of our own. It is based largely upon your lines; it is as comprehensive in its character and in its membership; and we hope in a small way is performing good work upon the same lines. We cannot claim such old organizations and such old industries as you have alluded to, sir; therefore, we must base our claims and we must base our pride on newer things; but it is also true that every one of those new things has had for its foundation ideas which were obtained from this side of the water. Now, we would not be worthy of you as your offspring if we had contented ourselves with simply receiving those suggestions or ideas, and not trying to extend and develop them. I am not going to take up more time now, but will content myself with saying that you have been to see us twice, and as there is luck in odd numbers, we are waiting to welcome you a third time. We thank you for what you are giving us on this occasion. We know from what we have already received what we are to get; and what pleases us the most and gives us the greatest joy is the spirit in which it is offered. It comes to us as from our friends—nay, closer than that, as from our brothers.

President Hadfield, in announcing that his Majesty the King had very graciously signified his willingness to receive a deputation from our American visitors, said: "This is indeed a great honor to pay to the technical man. I do not think that his Majesty has often received a body of technical men before, and

I think that we ought to consider ourselves highly honored on the occasion of his doing so next Friday. What is more, the Council have taken the somewhat unusual course of suggesting that we should present his Majesty with a Bessemer Gold Medal this year. We are specially glad to do that, because, on a previous occasion, his revered mother, our late Queen, was good enough to accept the medal; but we are very delighted that his Majesty has expressed his willingness to accept that medal."

President Hadfield, in announcing that Sir Hugh Bell, at the unanimous request of the Council, had expressed his willingness to take office as his successor, said: "Sir Hugh Bell's election to this honorable position will add fresh dignity and power to the position and work of the Iron and Steel Institute. A worthy son of a worthy sire, we wish him complete success in the high position to which he has been called. His revered father, Sir Lowthian Bell, was a master in the arts of metallurgy, and the world is to-day greatly benefiting from his many important researches on the scientific side of metallurgy. You will understand, and I may more freely say so after the eloquent words of Captain Hunt, that no country has benefited to a greater extent than America through the great labors of Sir Lowthian Bell in connection with blast-furnace work. Sir Hugh Bell is one of the original members and founders of our Institute; in fact, he is the senior member on the Council. He has always shown the warmest interest in the work of the Institute. Mr. Carnegie, in a letter to me on the subject, says, 'Sir Hugh Bell will make a model President, one well worthy and fit to occupy the Presidential chair.' May I also add to the congratulations to Sir Hugh Bell congratulations to Lady Bell? I may say that, with Sir Hugh in this office, we shall be indeed highly favored."

A Diploma of Honorary Membership in the Iron and Steel Institute was presented by President Hadfield to Professor Ehrenwerth, of Leoben, Austria, who, in accepting the honor, said: "I beg to return you most hearty thanks for this distinction, which, given by your great Institute, I look upon as the highest one I could receive."

Professor Bauerman referred to the great services of Professor Ehrenwerth sustantially as follows:

"It will be well known to all of us what a prominent position the great Austrian Iron Trade School has taken in the world, and you will remember our friend, Ritter von Tunner, who was for many years one of our most distinguished foreign members. Now, the best thing I can say for Professor Ehrenwerth is that I have known him for twenty-five years, and that all the good work that was done by Ritter von Tunner, of Leoben, in the old days is worthily carried on by Professor Ehrenwerth at the present time."

The second session, being a session of the American Institute of Mining Engineers, was held at the same place, Wednesday, July 25, at 10.30 a.m., President Hunt presiding. Mr. Hunt presented the following address:

President Hunt's Address.

While the actual dates of the organization of the American Institute of Mining Engineers and the introduction into America of the Bessemer process were not exactly identical, at the same time they were so close together that their histories have run largely parallel. Therefore it seems to me to be fitting upon the occasion of our holding this meeting in England, the birthplace of the Bessemer process, to give some account of its progress in America.

Unless inspiration is vouchsafed, prophecy is a very dangerous venture, and probably in no sphere has that danger been more clearly defined than in relation to the iron and steel industry. So frequently has it seemed as though the summit of all possible achievements had been reached, that the most astute minds have ventured to assert this conclusion. Again, physical conditions have apparently been so clearly unalterable that deductions as to the possible and impossible have seemed safe. This has been notably the case in America. It will be recalled that in the 'seventies a distinguished iron metallurgist, and a gentleman whom it has been the pride of both hemispheres to honor, visited America and carefully studied the iron and steel situation, with the result that he unhesitatingly proclaimed that the development of her possible production of iron, and influence in the markets of the world, were plainly limited by geographical conditions to such an extent that the

old world need not fear her rivalry. When this prophecy was made it seemed to be absolutely logical, and based upon conditions which could not be altered or overcome. Indeed, he gave actual figures showing that the transportation distances were so great over which it would be necessary to bring iron-ore and the fuel to smelt it to a common point, and then after its reduction the transportation of the products to market would again cover such distances, that it was impossible for successful commercial competition to be created. At that time the statement that iron-ore could be transported over one hundred miles of railway and eight hundred of water and placed at the then and now very center of the American iron industry at a cost of $2.40 per ton, would have been received as the wildest lunacy. That has all been accomplished, and instead of having brought disastrous results to the transportation interests, it has, on the contrary, yielded such profits that they have been built up to colossal proportions. And the finished product can be placed at the seaboard for foreign markets at transportation-cost little, if any, greater than is required for internal transportation in many European countries.

Mineral Resources of the South.

These low carrying-charges have been co-relative with a tremendous ore development in the Lake Superior region, which has steadily increased until in 1905 there were taken from there 34,353,456 gross tons. While there still remain many proved millions of tons of ore, it is recognized that such a production cannot be indefinitely maintained. This condition is leading to increased interest being taken in the other ore sections, some of which, while well known, have been unworked, either because of location or comparatively low iron-percentage of the ore. The mineral resources of the Southern States impressed Sir Lowthian Bell, when he was investigating iron-ore conditions, and he predicted a prosperous future in that region. For some years it seemed as though such hopes were doomed to disappointment; but there is no longer any doubt of the wisdom of the prediction. In 1880 the pig-iron production of all the Southern States was 387,000 gross tons. In 1905 it was about 3,100,000 gross tons. At the same time, it has not been in iron alone that the South has grown during

the past twenty-five years. In 1880 there was invested in cotton-mills about $21,000,000. In 1905 it had increased to $225,000,000. During the same period the capital invested in the Southern States in all kinds of manufactures increased from $257,000,000 to $1,500,000,000.

As might be expected, with this great revolution in cost of transportation there has also come a revolution in selling-prices.

While the political policy of the United States has tended to maintain a higher range of prices than would probably have prevailed under other conditions, at the same time it is true that, during a time of severe business depression, steel rails were made from ore mined at the head of Lake Superior, smelted with coke from Pennsylvania coal, transported about 500 miles to Chicago, and there sold, delivered, at $15 per gross ton, and at that price, under the then-existing conditions, were within the cost of manufacture.

It is most earnestly to be hoped that such times may not return, but if, under pressure, that could be accomplished some years ago, there is no reason to suppose that under similar stress the history could not be repeated. I mention this incident merely as a matter of record.

The First Bessemer Steel Made in the States.

It will be recalled that the first heat of Bessemer steel made in America was produced in an experimental plant in Wyandotte, Mich., in the autumn of 1864, and that the first commercial rolling of steel rails was in the Cambria Iron Co.'s mills at Johnstown, Pa., in August, 1867, from steel made by the Pennsylvania Steel Co., at Steelton, Pa. The development of the business was very rapid, but not always attended with profitable results.

In June, 1876, there were ten rail-mills in operation, and an eleventh nearly ready to start. At that time one Bessemer company had already gone to the wall. One of these ten companies, as well as the eleventh, and their works, have absolutely gone out of existence. In fact, but five of them are now making rails. One of these has but a limited production in that department, and the other four are making their rails in mills not then in existence, and in one case in a mill hundreds of miles away. It

is also true that three of the then-separate corporations have since been consolidated under a new title into one, which, with its new mill, is enumerated in the existing five; and this mill is situated some miles from the location of either of the original ones. Two of the other companies, while actively at work in other lines, have ceased making rails.

Since 1876, in addition to those already mentioned, seventeen corporations have erected mills to roll standard-weight steel rails, thirteen from steel of their own manufacture, and four from purchased blooms. Seven of the steel producers are now making rails, two are on other products, and the remaining eight have gone out of existence, so that there are now in the United States ten corporations running thirteen rail-mills. Of these, one company is rolling its rails from basic open-hearth steel; and another one from either that or Bessemer. I only refer to mills rolling rails of 60 lb. and over per yard.

Three of the companies are controlled by one parent corporation; three others by another, and two others by still another; thus leaving two single and independent concerns. In addition, the building of another mill of large capacity, to roll basic open-hearth rails, with the required blast-furnaces, steel furnaces, and town, is actively under way; this being done by one of the subsidiary companies of the United States Steel Corporation. The contemplated expenditure will amount to about $50,000,000.

Canada as a Producer.

In 1876 Canada did not possess a steel-rail mill of any kind. To-day there are two, situated about 1,500 miles apart, one practically on the shores of the Atlantic, and the other at the foot of Lake Superior. They naturally depend upon distinctly different sources for their supply of ore, fuel, etc. The Eastern works are producing basic open-hearth rails from iron made in their own blast-furnaces from near-by ores and fuel. The Western one is so far depending upon the Bessemer process, but has one basic open-hearth furnace about completed. As yet, the ores used by it are from Lake Superior deposits located in the United States, and the coal and coke are brought from the States of Ohio, Pennsylvania, and Virginia. That this is at all possible, well illustrates how low transportation-charges

have been brought. One of the two blast-furnaces of this establishment is run on American ores and Canadian charcoal, and is making a record production. Both works are operating successfully, and enjoying bounties from the Canadian Government, but as yet their production is not equal to the immediate demands of the Dominion.

While few words have been required to tell of the various changes named above, the attendant incidents have been startling and the results tremendous. In ten cases absolutely new communities have been organized, and these have grown to embrace thousands of people.

While I have not the actual tonnage of the rail-production of the several works in the earlier days, I have some of the records of their ingot-output, and as at that time rails were practically their only finished product, a comparative idea can be formed. Moreover, we do know the total rail-production of the country for the various years.

In a paper presented to the American Institute of Mining Engineers in 1876,[1] in which my patriotism sought vent in words, I pointed out some of the salient improvements in the mechanical details of American Bessemer plants which had made possible the then great increase in their production, and rightfully credited most of them to Alexander L. Holley, while at the same time giving what seemed to me due credit to others who up to that time had been prominent in the business.

It is a well-known matter of history that Mr. Holley was the first one to bring to America the Bessemer process in what I may call an organized condition, and that after several years of legal skirmishing a consolidation of the patent interests involved was effected, following which the erection of works to make steel by that process was quite rapid, and, with the exception of three, Holley acted as consulting engineer during their construction, and in fact during their subsequent operation, this connection lasting until his death in 1882. Two of the works with which he was not connected made disastrous financial failures, and while the other one was successful, it never ranked with several of its rivals in the matter of volume of output. So it was that Alexander L. Holley's personality

[1] *Trans.*, v., 201 to 216 (1876–77).

was indelibly stamped upon American Bessemer-steel making. Fortunately, his efforts were joined by those of a number of exceptionally capable men. The names of Holley, John Fritz, George Fritz, William R. Jones, Daniel L. Jones, and Robert Forsyth furnish a galaxy of talent which makes plain why America so soon forged to the front in Bessemer-steel production.

Bessemer vs. Open-Hearth Steel.

It will be recalled by the older of my foreign hearers that in his capacity of consulting engineer to the American Bessemer manufacturers, Holley made at least yearly visits to Europe, where, largely by reason of his charming and lovable personality, he received free access to practically all steel-works, and it was well understood by his hosts that he was seeking information to be used by his American clients. It was also known that, on the other hand, he was ready to give freely in return the best he had. Holley was peculiarly fitted for this post. The information he gained by observation was not used in mere copying, but rather served as a basis on which to build. The freedom of his mind from prejudice was well shown by his position toward the open-hearth processes, both acid and basic. Holley, in spite of his belief in and devotion to the Bessemer process, strongly urged upon his American clients the claims of the others; and it is historical that on the occasion of one of the Institute's meetings, when jokingly reminded by some of his Bessemer associates that it seemed strange for such advocacy to emanate from him, he replied: "You may think me crazy, but I believe that some of you will live to see the open-hearth process attend the funeral of the American Bessemer." The death has not yet occurred, and alas! he and many of his listeners have passed away, but some still live and know that some members of the American Bessemer family have at least begun to realize that the limitation of production by that process has been reached.

The Invention of the Blooming-Mill.

In my paper before mentioned I called attention to the invention by Mr. George Fritz, then chief engineer of the Cambria Iron Co., Johnstown, Pa., of the blooming-mill on which to roll steel ingots to blooms instead of reducing them by ham-

mering, as had been the practice. This was first accomplished in 1867 on a modified rail-train of rolls. Mr. Fritz built his first regular three-high blooming-mill in 1871. This departure from the old practice, added to Holley's modified converting-plants, greatly helped to increase production.

At the time of my Philadelphia paper, June, 1876, the Bessemer plant of the North Chicago Rolling-Mill Co., built from Holley's plans, and then under the charge of Mr. Robert Forsyth, held the record for a month's production of ingots at 6,457 gross tons. During the year 1876, there were made in the whole United States 469,639 gross tons of Bessemer ingots, from which 368,299 gross tons of rails were made, selling at an average price of $59.25 per ton with gold at $1.10.

There was a constant increase in production until 1887, when that of ingots reached 2,936,035 tons and rails 2,101,904 tons; the latter sold at an average price of $37.08 per ton, with currency at par. 1887 was a year of unparalleled railroad building in the United States, followed by a period of reaction, with the result that while the output of ingots kept up that of rails fell off, and it was not until 1899 that the rail production again passed the two-million-ton point. In that year there were turned out 7,586,354 tons of Bessemer ingots, 2,947,316 tons of open-hearth ingots, and 2,270,585 tons of rails, all of Bessemer steel, the latter selling for an average price of $28.12 per ton. Following that year there was a continued increase in the output of open-hearth steel, while that of Bessemer remained more nearly constant; until in 1905 there were made 10,919,272 gross tons of Bessemer ingots, 8,444,836 gross tons of open-hearth ingots, and 3,375,611 gross tons of rails, 183,264 tons of which were of basic open-hearth steel. The rails were practically all sold at a uniform price of $28 per ton, which has been the standard price since, and including, 1902.

I have referred to the changes which have taken place in the organizations of steel companies and the location of their plants, and I have stated that the North Chicago Rolling-Mill Co. held the monthly record for product of Bessemer ingots in 1876. In 1882 this company built an entirely new Bessemer and rail plant at South Chicago, about fifteen miles away from its old one. The converting-works were designed and erected by Mr. Robert Forsyth. In 1889 these works were included in the

consolidation forming the Illinois Steel Co. Later the North Chicago plant was dismantled. At first the new rail-mill was a reversing one, but following its acquisition by the new company Mr. Forsyth, who, after an interim of several years, then returned to the management, entirely remodeled it by putting in a three-high mill with automatic tables. There have been changes in the management and additions to the plant since then, but, fundamentally, the converting-works and mill are the same, and their record production is 91,424 gross tons of ingots and 71,424 gross tons of rails in a month. All of these rails were rolled on one rail-mill. It consists of three sets of rolls, beside the blooming-train, set in échelon, but making one mill, all the steel being reduced through the same passes in the rolls.

Captain Jones and Mr. Carnegie.

In 1886 the rail-mill of the Edgar Thomson Works had been doing great work, but it was being pressed in output by other mills, and Mr. Andrew Carnegie then, as on many other occasions, displayed his acute business acumen, and directed Captain Wm. R. Jones, manager of the works, to prepare plans for the very best rail-mill he knew how to design. Captain Jones, in one of our many intimate talks, told me that some time afterwards Mr. Carnegie asked him how he was progressing with his plans, and, on his reporting, asked how much the mill would cost. The Captain replied that he could not then tell. Mr. Carnegie said, "Well, but we must place some limit on its cost!" Jones answered, "You told me to design the very best mill in my power; now if I am to be limited by the cost-sheet in so doing, I must give up the job." Mr. Carnegie then asked, "But if we build such a mill, how much will you promise to increase its production over the present one, and how much per ton will you save?" Jones answered, "I will promise to double the output, and save 50 cents per ton." "All right," was the answer, "go ahead, and do your best." The new mill started in 1888, and all promises for it have been much more than fulfilled. Its record production of rails for a month is 61,033 gross tons. There are three sets of rolls in this mill, which are placed tandem. It has been strengthened since Captain Jones's death, but is practically his mill. The converting-works, which were originally designed by A. L. Holley, afterwards altered and

added to by Jones, and again by C. M. Schwab, have made about 105,000 gross tons of ingots in a month. After the starting of the new mill, the original Edgar Thomson rail-mill remained idle for several years. It was then remodeled and used for the production of rails, mostly under 60 lb. per yard, and has been in practically constant operation ever since. Within the last year another rail-mill has been added to the plant, and one which is quite a departure in the business. It consists of two sets of 18-in. rolls, placed tandem, and equipped with automatic tables, the power for both rolls and tables being electric. It is intended to use this mill for the reduction of second-quality rails of standard sections, made in the other mills, to lighter ones, but as yet it has been principally used for rolling small-sectioned rails from billets.

Another notable happening in American rail-making history was the consolidation of the Lackawanna Iron & Steel Co. and the Scranton Steel Co., both of which were located in Scranton, Pa. Following it, the rail-mill of the former company was abandoned, all the work being given to the latter, which was of more recent construction, and was of the reversing type, and with one other constituted the only existing examples of such mills in America. The other one was built by Mr. A. J. Moxham, as President of the Johnson Co., in 1888, near Johnstown, Pa., to roll steel-girder street-car rails. In 1894 this mill was removed to Lorain, Ohio, and is now operated by one of the subsidiary companies of the United States Steel Corporation. While its principal output is girder and other street-car rails, a large tonnage of standard shapes is also produced.

The Lackawanna Steel Co. decided to abandon Scranton as a manufacturing point, selecting a new location at West Seneca, N. Y., on Lake Erie, near the city of Buffalo. In placing the rail-mill in its new location some changes were made, but the reversing type was retained. Rail-rolling was resumed upon it in October, 1903. It is somewhat remarkable that the reversing rail-mills in America should have developed such a migratory disposition. I am certain from personal knowledge that in neither case was it caused by unsatisfactory foundations. It is a matter of record that when putting in the foundations at Scranton, Pa., Mr. W. W. Scranton, who built the works, made an innovation on American engineering practice by using con-

crete, instead of stone or brick, in its foundations, and with such complete success that the practice soon became general.

I have mentioned the record tonnage of but two plants, because they have been the largest, and strikingly illustrate the great increase in American output. But all the other American works are running splendidly.

The Casting-Pit Abandoned.

Among the mechanical improvements of the Bessemer converting plants, which did much to increase their output, was the abandonment of the casting-pit, and the adoption of the present practice of filling the molds while standing on cars, which are immediately thereafter pulled outside of the converting-works, and subsequently, when the steel has sufficiently cooled, the molds are mechanically stripped from it, thus saving much manual labor and time; in fact, without this improvement in practice the present output would be impossible. Holley's shallow pit was the first step—this, seemingly, the final one. I do not know which works first adopted the plan, but it will be found by reference to the Institute's *Transactions*, vol. xiii., that at its New York meeting, February, 1885, L. G. Laureau read a paper in which he proposed so casting and handling the steel. He called attention to the fact that both in England and on the Continent ingots were sometimes cast from a ladle into molds placed on cars, and said, "I believe the solution of the problem lies in casting the ingots into molds placed on cars so constructed that all subsequent operations, such as stripping and putting back into place, may be done automatically, or by easily-handled machinery." Further: "The pit and the ingot-cranes can be entirely suppressed, and all the operations of casting, cleaning, ladle-changing, etc., can take place on the general level." But his plan was to turn the filled molds on their sides, and force the ingots out by a hydraulic plunger. Captain Jones subsequently adopted at the Edgar Thomson Works that part of the proposed practice. But it was found that with the larger-sectioned ingots, which had come into use, this hasty placing of them on their sides increased the prevalence of pipes; so it, as well as the use of horizontal heating-furnace, was abandoned.

The Use of Metal Direct From the Furnace.

Another factor in increasing output was the use of metal direct from the blast-furnaces. This not only added to production, but at the same time decreased cost by saving the expense of re-melting; but it was not entirely successful until the mixer invented by Wm. R. Jones was adopted. The claim that the credit of this, as an invention, belonged to him was after his death bitterly fought, and the case carried to the U. S. Supreme Court, which decided in favor of his claim; therefore it must be so considered. That he was the first to venture to accumulate 150 tons and over of molten metal in a refractory-lined vessel, to be drawn therefrom as wanted and taken to the converters, has never been denied.

The Edgar Thomson works, then under his management, were running on direct metal, and experiencing the usual troubles incident to its use. In seeking for a way to eliminate them, he planned the mixer. This was soon after the works began the use of natural gas, and he expected to be compelled to rely upon heat from it to keep his iron sufficiently hot. He also thought it might be necessary to agitate the metal while in the mixer to insure sufficiently uniform results; and so designed his apparatus. Neither procedure was found necessary. I have wondered if the use of natural gas had not been possible, would he have made the venture? Undoubtedly the invention would have come in time, but probably would have been much delayed.

It is with some modest hesitation that I refer to the part which mechanical appliances at the rolls have performed in the great increase in steel-rail output; but without them it would have been impossible. Until March, 1884, all American rail-mills were fed by the use of hooks and tongs; and three-high trains required from fifteen to seventeen men to operate them for a production limited to 300 tons per turn of twelve hours. Numerous inventors had sought to accomplish this work by machinery which would be automatic in its action, but I believe until that time there had not been any actually built. Its possibility was discussed and predicted; and indeed, as I have recorded on another occasion, Holley said, in that spirit of prophetic jest so constant and so charming in him, "that the day would come when we would start a rail-mill on Monday morn-

ing, and then go home after locking the doors, only returning each morning to count the rails that had been made during the preceding twenty-four hours, no other manual labor being necessary." That point has not been reached, and in fact the output has become so rapid, that if the count were not kept as the rails are made, I fear the enumerator would never catch up. How Holley would have reveled in the knowledge of what is being accomplished! He knew that rail-mill mechanism was possible, but for some incomprehensible reason the way did not open to his mind.

Automatic Tables.

In March, 1884, I introduced driven tables in front of the finishing-rolls of the rail-train of the Albany & Rensselaer Iron & Steel Co., Troy, N. Y. They worked so well that I put an automatic arrangement in front of the roughing-rolls. This was more particularly designed by Mr. Max M. Suppes, then the master mechanic of the department, and now general manager of the Lorain works of the U. S. Steel Co. Mr. Suppes rendered me valuable assistance during all my experiments. The last table was also successful, and soon after I placed tables on the catchers' side of the train.

Capt. Wm. R. Jones at once advised his firm to secure authority and apply the system to the Edgar Thomson mill. This being done, he designed and put in an elaborate system of tables, some points of which he patented. He, Mr. Suppes, and myself pooled our interests, and later nearly all of the steel companies of the country secured licenses from us. The number of men necessary to operate the rolls was at once reduced from seventeen to five, and I have already given the figures covering the increased production. From 300 to 3,000 tons per day is a far cry.

Others took up the automatic-table matter, and Mr. F. H. Treat, then mechanical engineer of the Joliet Steel Co., put in a set after his designs at their Joliet, Ill., mill. He was assisted in this by Mr. Charles Pettigrew, the company's chief engineer. Mr. Wm. Clark, of Pittsburg, also developed a table system. As before stated, there have been great changes in the various companies' mills, but the table designs are all based on the original schemes.

I have mentioned by name but few persons, and the majority

of those are either deceased or not now actively connected with steelmaking. But this does not mean that all credit belongs only to those so named. Far from it. There has been and is now an army of workers, some of whom have reaped rich pecuniary rewards; others are still in the hottest of the conflict, no doubt hoping for personal success and emoluments, but, over and above all other considerations, giving their best toward the success of their works. I cannot mention them all, and whom could I select?

It must be remembered that these men have improved and strengthened the plants which they manage or have designed, and with that and their administrative efforts have come the great results. To be content with conditions as they found them would have been to such men impossible.

Steel Rails Supersede Iron.

Demand creates supply; therefore there would not have been the increased steel production in America if it had not been for the development and growth of the country, and it is collaterally true that without the discovery and expansion of the making of Bessemer and other mild steels that growth would have been impossible. While the present American railways with their equipment would be absolutely impossible with iron rails, it is also true that their development has necessitated a change in the characteristics of the steel rails used. In the early 'seventies, when steel rails began to replace iron ones, the section required was not over 60 lb., and more generally 56 lb. to 58 lb., to the yard, and the increased service obtained from them was regarded as wonderful. But, nevertheless, the wisdom of their use was not at once unanimously accepted. If I am not mistaken, one of the leading English technical journals for a long time warmly championed the continued use of iron rails. Naturally, the term "steel" carried with it an idea of hardness, and consequent brittleness; hence the fear of an all-steel rail. Much time and money were spent in unsuccessful experiments with iron ones having steel heads. These conditions led to making the steel rails of as soft a composition as could then be successfully accomplished. I have no doubt that had ferromanganese been then known the early rails would have been rolled from dead soft metal. Let this be as it may, it is true

that while the early steel rails were of very irregular chemical composition, the aim was to keep the carbon content not to exceed 0.30 per cent., and somewhat later not over 0.40 per cent. Undoubtedly, owing largely to the care exercised in the physical treatment of the metal during the manufacture of the rails. most excellent results were obtained, and gradually familiarity with them dispelled the fear of breakage. And it was not long before railway officials realized that their use permitted increased loads and speed. Traffic demands and better financial conditions led to increasing the weight of the rail-sections, and also the hardness of the metal in them; but the same causes also led to heavier wheel-loads of both engines and cars, and faster schedules. In many cases the results as to wear were not satisfactory, which led to a notable discussion, which is recorded in the *Transactions* of the Institute. The advocacy of softer steel came from one of the leading railway systems of the country, ably presented by their chief chemist, then, as now, a distinguished member of the Institute. This resulted in a demand for lower-carbon steel, which continued for several years. But the results were not as anticipated. The increase of wheel-loads, total tonnage hauled, and speed of trains went on, and harder steel won the day, and has since been in universal use on American roads. But the enlargement of elements was not all on the side of the railways. The railmakers had also been busy, and some persons claimed, and still contend, that speed of manufacture did not tend to give better results under stress of traffic. Let that be as it may, it is a fact that American railways now require very much harder rails than do those of Europe, and this regardless of the climatic conditions under which the rails are to be used. In fact, thousands of tons of 80-lb. rails, with carbon content to the height of American specifications, have been, and are, in safe use on Canadian roads, some of them made on this side of the water, some in the United States, and others in Canada.

Basic Open-Hearth Steel.

The increase in the output of basic open-hearth steel has been great in the United States; but it was not until 1899 that the commercial manufacture of rails from that metal was begun. This was done at the Ensley, Ala., works of the Ten-

nessee Coal, Iron & Railroad Co., and since then that company has regularly continued the manufacture.

The Colorado Fuel & Iron Co., at Pueblo, Colo., has begun the manufacture of basic open-hearth rails on a large scale.

As I have already mentioned, the entire rail output of the Dominion Steel Co., of Sydney, Nova Scotia, is of that metal. And the Indiana Steel Co., a subsidiary company of the United States Steel Corporation, has started upon the building of a large plant for the same purpose. Aside from the comparative merits of Bessemer and basic open-hearth steel, there seems to be no doubt but that America's iron-ore conditions will force the growth of the latter process. As I have already stated, in 1905 there were rolled in the United States 183,264 tons of basic open-hearth rails, which is small as compared to the Bessemer tonnage, but it is "the handwriting on the wall!" There have been two attempts to make steel in America by the basic Bessemer process. Both were technically successful, but, owing to the character and cost of the iron obtainable, they failed commercially.

While so far the output has covered but a moderate tonnage, at the same time the successful results obtained demand that mention be made of the McKenna process of renewing worn rails. The American McKenna Process Co. owns three mills, but at present only one of them is in operation. It is situated at Joliet, Ill., and has been continuously successful. As you will recall, the procedure is to take worn rails, heat them in long furnaces, and give them, while at a comparatively low temperature, two passes in a tandem mill. The reduction varies with the condition of the worn section, but, as a rule, gives a rail of about from 10 per cent. to 12 per cent. lighter weight than the original section. This practice has been in operation since 1897, and a number of the leading Western railway systems are regularly employing it with satisfactory results.

Rolling of Structural Shapes.

Another line of steel manufacture has had a great growth in the United States. That is the rolling of structural shapes, practically all of which are of steel. Naturally the demand, and so the output, has varied. I find that in 1902 there were rolled

1,300,326 tons; in 1904 it fell to 949,146 tons; while in 1905 it was 1,660,519 gross tons, being 28 per cent. over 1902 and 74.9 per cent. over 1904.

While I have given precedence to the American development of Bessemer and open-hearth steels, particularly as intended for rails, it was because, as stated, that history has been so coincident with that of our Institute. But it has not been on those lines alone that America has made great progress. In fact it was necessary to such production of steel that increase in the blast-furnace output should at least keep pace with it. The ore had to be smelted preparatory to the subsequent processes. It will be recalled that European and American ironmasters differed for a long time as to the economy of forcing the workings of blast-furnaces, the former contending that while the output would be augmented, so also would the cost of repairs. On the other hand, the Americans maintained that it was as to the cost per ton, and not as to time, that such cost should be figured. That is, if a furnace-lining gave, say, 100,000 tons of metal and lasted but a year in so doing, it was cheaper thus to use the plant than to take three years in obtaining the same product. At all events, it has been on the latter lines that the business has been conducted. But, as in many other cases, we had to come to England for that which has made such driving possible. Without the firebrick stoves it could not have been accomplished. They may have been improved, and other names deserve honor for what has been done, but that of Whitwell will ever stand as the foundation one.

The production of pig-iron of all kinds in the United States in 1876 was 1,868,961 gross tons. In 1905 it was 22,992,380 gross tons. The production of Bessemer pig-iron was not separated statistically from other pig-iron until 1887. In that year it was 2,875,462 gross tons, and in 1905 it was 12,220,209 gross tons. The production of basic pig-iron was first separately ascertained in 1875, when it was 336,403 gross tons. In 1905 it was 4,105,179 gross tons, charcoal basic pig-iron not being considered in either case.

The Jones Mixer.

Undoubtedly the use of the Jones scheme of a mixing receptacle has done much to permit the driving of the blast-furnaces supplying steel plants. The output of several furnaces being

so treated, it is readily seen that greater variation can be permitted in its character than if the iron from each one had to be used separately. But while furnaces have been driven to making an output of over 750 tons per day apiece, I believe it has been concluded that better results are obtained by limiting the output of the same furnaces to about 550 tons per 24 hr. Of course, the tremendous outputs would be impossible if the raw materials, and in fact the produced metal, were not handled by machinery, much of which is of automatic character. Such devices do not merely move the stock, but some of them also regulate the charging and distribution of it in the furnace, and contribute to the regularity of the metallurgical process. In that field there has been much mechanical ability applied, and improvements are still being diligently sought. Next to the use of gas blowing-engines, and for which we must thank this hemisphere, I suppose the development in blast-furnace practice which is attracting the most attention in America is our past-President James Gayley's application of refrigeration to the blast, the results from which are certainly very encouraging, and I am glad to know that its use is being taken up by other concerns than his own.

Gentlemen, there are many other developments in the iron and steel art in America which deserve recognition, and I feel derelict in failing to mention any one of them, but time must limit my address. American members of the American Institute of Mining Engineers know of them. Our foreign members and our hosts of the Iron and Steel Institute must come to America and see for themselves. They may not want to copy, but they can, at least, see what to avoid.

The Iron and Steel Institute is fortunate in having been made the custodian of funds from which it can bestow emblems of honor upon gentlemen who have distinguished themselves in the field covered by the purposes of the Institute's organization. In making such awards, its Council have seen fit to recognize several members of the American Institute of Mining Engineers by awarding to them the Bessemer medal, and I can assure our hosts that in this recognition of the merits of its members our whole Institute has been honored.

As an individual association, the American Institute of Mining Engineers have not a medal of their own to bestow, but they

have the power to give that which seems to them to possess claims to desirability. We, however, have not been very lavish of this distinction. Under our rules it can be possessed by twenty persons at the same time, but there have seldom or never been more than ten, and our latest printed roll shows only eight. And, what is still more remarkable, there is no English name upon it, while in the past it bore the names oı Bell, Percy, Roberts-Austen, and Siemens. The Council of the American Institute of Mining Engineers felt that the occasion of this meeting in England, as the guests of the Iron and Steel Institute, was a fitting time to bestow upon two distinguished Englishmen, members of the latter society, our Institute's greatest recognition of merit. In making the awards it was felt that, if looked upon in a competitive sense, the task of selection was a hopeless one; all could not be honored; but it was also felt that in designating two gentlemen on whom the Iron and Steel Institute in 1901 and 1904 bestowed the Bessemer medal—men who have given such service in the investigation and development of the art of steelmaking—our society would be honored equally with the recipients. Therefore it is my very pleasant duty to announce, on behalf of the American Institute of Mining Engineers, the election to Honorary Membership in that society of John Edward Stead, F.R.S., and President Robert Abbot Hadfield, and to present to each of those gentlemen a properly engrossed certificate of such membership.

Mr. Hadfield, in returning thanks, remarked: "The announcement which the President has made about me is not a novel one, because he was good enough to communicate the fact to me a short time ago. I need hardly say how very greatly I esteem the honor you have seen fit to confer upon me, and I take it not only as a compliment to myself, but to the metallurgical industry of England. Your desire to confer this honor upon an Englishman who has received so much from your country is worth more than any orders or insignia, and I shall ever highly prize it. I have been a member of the American Institute for some fifteen years, and wear with satisfaction its Order this day, and I shall ever remember the cordial manner in which I have always been

received in your country; again I return my most profound thanks for the honor that has been bestowed upon me. Before sitting down I would like to express what every member present feels—viz., the satisfaction with which we have heard the President's Address. We know that he has taken an interest not only in theoretical matters, but he has done an enormous amount of practical detail, which, I think, shows why it is that America is to-day at the head of the iron and steel industry. By attention to practical details by such men as the late revered Mr. Holley and many others, they have laid the foundation of their success."

Mr. J. E. Stead also returned thanks for the honorary membership, saying: "Like Mr. Hadfield, I have been a member of the American Institute for a good many years. I sought to be on the ordinary membership in consequence of the society having so many prominent, eminent, and learned metallurgists in its ranks. I noticed, as they all had found, and the English members had also found, that the papers of that society were most valuable; and the reason why I sought membership was because I gained so much by reading those papers. I consider the ordinary membership is an honor, and you can understand how much greater I feel the honor conferred upon me of honorary membership. It certainly was a proud day in my life when I received a letter from Dr. Raymond telling me that I had been elected in the capacity of an honorary member. I consider this not only an honor to myself, but it is a great compliment to the Iron and Steel Institute. I also regard it as a link which will tend to bind together the two great English-speaking nations of America and England. I thank you very sincerely for the honor you have conferred upon me."

The third and concluding session, being a joint session of the American Institute of Mining Engineers and the Iron and Steel Institute, was held at the same place, Thursday, July 27, at 10.30 a.m. At the request of President Hadfield, the meeting was presided over by President Hunt.

The following papers were presented in oral abstract by their authors:

The Roe Puddling Process, by James P. Roe, Pottstown, Pa.

Mr. Roe's paper was orally discussed by Dr. Raymond, Axel Sahlin, E. S. Cook, F. W. Paul, Prof. H. Bauerman, Prof. Turner, and B. Talbot.

Improvements in Rolling Iron and Steel, by James E. York, New York, N. Y.[1]

Mr. York's paper was orally discussed by President Hunt, Kurt Kerlen, and James Riley.[2]

Comparison of American and Foreign Rail-Specifications; with a Proposed Standard Specification to Cover American Rails Rolled for Export, by Albert Ladd Colby, New York, N.Y.[3]

Mr. Colby's paper was discussed orally by Messrs. Raymond, Windsor Richards, Williams, Harbord, Hadfield, Stead, York, and Lambert, and in correspondence by Messrs. Kenney, Sauveur, Frier, Webster, Palmer and Nijone.[4]

The Gas-Producer as an Auxiliary in Iron Blast-Furnace Practice, by R. H. Lee, Liberty Furnace, Va.[5]

Mr. Lee's paper was orally discussed by Messrs. Pollen and Havard, and, in correspondence, by Prof. Wm. E. Kent.[6]

The following papers were presented in oral abstract by the Secretary in the absence of the author:

The Design of Blast-Furnace Gas-Engines in Belgium, by Professor H. Hubert, Liège, Belgium.[7]

The Application of Large Gas-Engines in the German Iron and Steel Industries, by K. Reinhardt, Dortmund, Germany.[8]

The following paper was presented in oral abstract by the author:

Notes on Large Gas-Engines Built in Great Britain, and Upon Gas-Cleaning, by Tom Westgarth, Middlesbrough, England.[9]

The above papers on gas-engine practice were orally discussed by Messrs. Greiner, Westgarth, Raymond, Kent, Duff, Hamilton, Tannent-Walker, Robertson, and Thwaite.[10]

During the sessions the following papers of the American

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[1] *Bi-Monthly Bulletin*, No. 9, May, 1906, pp. 337 to 357.
[2] To be published in *Bi-Monthly Bulletin*, No. 13, January, 1907.
[3] *Bi-Monthly Bulletin*, No. 11, September, 1906, pp. 629 to 680.
[4] To be published in *Bi-Monthly Bulletin*, No. 13, January, 1907.
[5] *Bi-Monthly Bulletin*, No. 10, July, 1906, pp. 585 to 590.
[6] To be published in *Bi-Monthly Bulletin*, No. 13, January, 1907.
[7] See p. 909 of this *Bulletin* (*Bi-Monthly Bulletin*, No. 12, November, 1906).
[8] See p. 1037 of this *Bulletin* (*Bi-Monthly Bulletin*, No. 12, November, 1906).
[9] See p. 971 of this *Bulletin* (*Bi-Monthly Bulletin*, No. 12, November, 1906).
[10] To be published in *Bi-Monthly Bulletin*, No. 13, January, 1907.

Institute of Mining Engineers, in pamphlet form, were also distributed:

Piping and Segregation in Steel-Ingots, by Henry M. Howe, New York, N. Y.

Effect of Low Temperature on the Recovery of Steel from Overstrain, by E. J. McCaustland, Ithaca, N. Y.[11]

A Simple Rotary Distributor for Blast-Furnace Charges, by David Baker, Philadelphia, Pa.[12]

A New Colorimeter for the Determination of Carbon in Steel, by Chas. H. White, Cambridge, Mass.[13]

Internal Stresses and Strains in Iron and Steel, by Henry D. Hibbard, Plainfield, N. J.[14]

Heat-Treatment of Steels Containing Fifty-Hundredths Per Cent. and Eighty-Hundredths Per Cent. of Carbon, by C. E. Corson, Latrobe, Pa.[15]

Methods of Mining, Hauling and Screening at the Mines of the Aldrich Mining Company at Brilliant, Ala., by T. H. Aldrich, Jr., Birmingham, Ala.[16]

The following papers of the American Institute of Mining Engineers were read by title:

The Genesis of Ore-Deposits, by George J. Bancroft, Denver, Colo.

The Washoe Plant of the Anaconda Copper-Mining Company in 1905, by L. S. Austin, Houghton, Mich.[17]

The Tin-Deposits of the Kinta Valley, by William R. Rumbold, Oruro, Bolivia, So. Am.

The Amalgamation of Gold-Ores, by Thomas T. Read, New York, N. Y.[18]

The Lime-Roasting of Galena, by Walter R. Ingalls, New York, N. Y.[19]

The Clays of Texas, by Heinrich Ries, Ithaca, N. Y.[20]

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[11] *Bi-Monthly Bulletin*, No. 9, May, 1906, pp. 447 to 466; No. 10, September, 1906, pp. 621 to 628.

[12] *Bi-Monthly Bulletin*, No. 10, July, 1906, pp. 523 to 528.

[13] *Bi-Monthly Bulletin*, No. 11, September, 1906, pp. 743 to 748.

[14] *Bi-Monthly Bulletin*, No. 11, September, 1906, pp. 707 to 724.

[15] *Bi-Monthly Bulletin*, No. 11, September, 1906, pp. 725 to 742.

[16] *Bi-Monthly Bulletin*, No. 10, July, 1906, pp. 591 to 610.

[17] *Bi-Monthly Bulletin*, No. 10, July, 1906, pp. 529 to 584.

[18] *Bi-Monthly Bulletin*, No. 9, May, 1906, pp. 467 to 496.

[19] *Bi-Monthly Bulletin*, No. 11, September, 1906, pp. 681 to 700.

[20] *Bi-Monthly Bulletin*, No. 11, September, 1906, pp. 767 to 806.

A Device for Regulating the Discharge of Water from a Reservoir, by P. Bouéry, Weaverville, Cal.[21]

The Cyanidation of Raw Pyritic Concentrates, by F. C. Smith, Wenden, Ariz.

Studies on Refining and Overpoling of Copper, by H. O. Hofman, Boston, Mass.

The Constitution of Ferro-Cuprous Sulphides, by H. O. Hofman, Boston, Mass.

Lime-Roasting with Special Reference to the Savelsberg Process, by H. O. Hofman, Boston, Mass.

The Geology of Deutschman's Cave near Glacier, Alberta Can., by W. S. Ayres, Hazelton, Pa.

A Search for the Causes of Injury to Vegetation by Smoke, by Persifor Frazer, Philadelphia, Pa.

Discussion of Paper by Mr. Watson on "Lead- and Zinc-Deposits of the Virginia-Tennessee Region," by Frank Firmstone, Easton, Pa.

The following papers of the Iron and Steel Institute, in pamphlet form, were also distributed:

The Influence of Silicon and Graphite on the Open-Hearth Process, by Alex. S. Thomas, Cardiff, Wales.[22]

The Crystallography of Iron, by F. Osmond and G. Cartaud, Paris, France.[23]

The Kjellin Electric Steel-Furnace, by E. C. Ibbotson, Sheffield, England.[24]

The Constitution of Iron-Carbon Alloys, by Albert Sauveur, Cambridge, Mass.[25]

Tempering and Cutting-Tests of High-Speed Steel, by H. C. H. Carpenter, Teddington, Eng.

Recent Processes in Machine-Molding Practice, by Ph. Bonvillain, Paris, France.

Different Modes of Blast Refrigeration and Their Power Requirements, by J. E. Johnson, Jr., Longdale, Va.

The Nodulizing and Desulphurization of Fine Iron-Ores and Pyrites-Cinder, by Albert Ladd Colby, New York, N. Y.

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[21] *Bi-Monthly Bulletin*, No. 11, September, 1906, pp. 749 to 754.

[22] See pp. 931 of this *Bulletin* (*Bi-Monthly Bulletin*, No. 12, November, 1906).

[23] See pp. 989 of this *Bulletin* (*Bi-Monthly Bulletin*, No. 12, November, 1906).

[24] See pp. 967 of this *Bulletin* (*Bi-Monthly Balletin*, No. 12, November, 1906).

[25] See pp. 939 of this *Bulletin* (*Bi-Monthly Bulletin*, No. 12, November, 1906).

Members and Visitors Registered at London.

The following list, which in all probability does not contain the names of all who attended the sessions and excursions, is composed of the names of members and guests registered at headquarters.

Mr. Edwin Adams, Manchester.
Mr. E. Adamson, West Hartlepool.
Mrs. E. Adamson, West Hartlepool.
Mr. Harold Adamson, Hyde.
Mr. Joseph Adamson, Hyde.
Mrs. Joseph Adamson, Hyde.
Mr. William Affleck, Ellsworth, Pa.
Mr. E. T. Agius, London.
Mr. G. Ainsworth, Consett.
Miss Ainsworth, Consett.
Mr. Samuel Allen, Edgbaston.
Mr. William Edgar Allen, Sheffield.
Sir J. T. N. Alleyne, Bart., Belper.
Miss Alleyne, Belper.
Mr. M. H. Allott, Rotherham.
Mrs. M. H. Allott, Rotherham.
Mr. James A. Anderson, Greenock.
Mr. E. G. Appleby, London.
Mrs. E. G. Appleby, London.
Mr. Robert Armitage, Leeds.
Mr. Thomas Ashbury, Manchester.
Mrs. Sarah Ashbury, Manchester.
Mr. John A. F. Aspinall, Liverpool.
Mr. Albert J. Astbury, Birmingham.
Mrs. A. J. Astbury, Birmingham.
Mr. L. H. Atkinson London.
Mr. A. M. Austin, New York, N. Y.
Mrs. A. M. Austin, New York, N. Y.
Capt. R. K. Bagnall-Wild, London.
Mrs. R. K. Bagnall-Wild, London.
Mr. Thomas H. Bailey, Birmingham.
Mrs. Thomas H. Bailey, Birmingham.
Mr. Hugh A. Bain, Riverside, Cal.
Mrs. Hugh A. Bain, Riverside, Cal.
Mr. H. Kelway Bamber, London.
Mr. Ernest Jefferson Barnes, Sheffield
Mr. Geo. D. Barron, Rye, New York.
Mrs. Geo. D. Barron, Rye, New York.
Miss Dorothy Barron, Rye, New York.
Miss M. Elena Barron, Rye, New York.
Mr. Herbert Bates, Manchester.
Mr. William Ralph Bates, Derbyshire.
Mrs. William Ralph Bates, Derbyshire.
Prof. H. Bauerman, London.
Mr. Jacob Becker, Kalk, near Cologne.
Mr. J. C. Beeley, Hyde, near Manchester.
Dr. Robert Bell, Ottawa, Can.
Mrs. Robert Bell, Ottawa, Can.
Sir Hugh Bell, Bart., London.
Lady Bell, London.
Miss Benson, London.
Mr. R. S. Benson, Thornaby-on-Tees.
Mr. G. H. Bentley, Manchester.
Miss L. Bentley, Manchester.
Mr. E. Bernheim, Pittsburg, Pa.
Mr. Clarence Bird, London.
Mrs. Clarence Bird, London.
Mr. Fred. Bland, Sheffield.
Mrs. Fred. Bland, Sheffield.
Mr. W. H. Bleckly, Warrington.
Mr. Clifford E. Bloomer, Halesowen.
Mr. J. E. Alger Blyde, Sheffield.
Mrs. J. E. Alger Blyde, Sheffield.
Mr. Arthur Booth, Leeds.
Mrs. Arthur Booth, Leeds.
Mr. William Booth, Leeds.
Mrs. William Booth, Leeds.
Mr. James Bott, Egglescliffe, Durham.
Mrs. James Bott, Egglescliffe, Durham.
Mr. George R. H. Bowden, Gloucester.
Mrs. George R. H. Bowden, Gloucester.
Mr. Harold Bowman, Preston.
Mr. Harold E. Bowman, Preston.
Mr. Cyrus Braby, London.
Mrs. Cyrus Braby, London.
Mr. R. Watson Bradley, Stirlingshire.
Mrs. R. Watson Bradley, Stirlingshire.
Mr. V. M. Braschi, Mexico City, Mex.
Mrs. V. M. Braschi, Mexico City, Mex.
Miss Briggs, Eccles.
Mr. William Bright, Gowerton.
Mr. Fred. S. Brightmore, Doncaster.
Mrs. M. M. M. Brightmore, Doncaster.
Mr. Wallace Broad, Shanghai.
Miss Broad, Shanghai.
Mr. B. J. Broadway, Birmingham.
Miss Broadway, Birmingham.
Mr. J. E. Brooks, Leeds.

Mrs. J. E. Brooks, Leeds.
Mr. Bennett H. Brough, London.
Mrs. Bennett H. Brough, London.
Mr. H. W. Brown, Sheffield.
Mr. P. B. Brown, London.
Mrs. P. B. Brown, London.
Mr. James D. Bruce, Knoxville, Tenn.
Mrs. A. M. Buchanan, Cardiff.
Mr. H. A. Bueck, Berlin.
Mr. C. Bullock, Manchester.
Mrs. C. Bullock, Manchester.
Mr. A. M. Butchart, Barrow-in-Furness.
Mrs. A. M. Butchart, Barrow-in-Furness.
Mr. Basil Harding Butler, Leeds.
Mr. Edmund Butler, Leeds.
Mrs. Edmund Butler, Leeds.
Miss Butler, Leeds.
Mr. Harold Butler, Halifax, N. S.
Mrs. Harold Butler, Halifax, N. S.
Mr. Thomas Campbell, Glasgow.
Mrs. Thomas Campbell, Glasgow.
Mr. Alfred Campion, Glasgow.
Mr. Athol John Capron, Sheffield.
Mr. Charles George Carlisle, Sheffield.
Mrs. Charles George Carlisle, Sheffield.
Mr. Edward Carlisle, Workington.
Mrs. Edward Carlisle, Workington.
Mr. A. E. Carlton, New York, N. Y.
Mrs. A. E. Carlton, New York, N. Y.
Mr. David Carnegie, Sheffield.
Mr. Charles George Carson, London.
Mr. Charles Catlett, Staunton, Va.
Mrs. Charles Catlett, Staunton, Va.
Miss Catlett, Staunton, Va.
Mr. Geo. Cawley, London.
Mrs. Geo. Cawley, London.
Mr. H. S. Chamberlain, Chattanooga.
Mrs. H. S. Chamberlain, Chattanooga.
Mr. W. F. Cheesewright, London.
Mrs. W. F. Cheesewright, London.
Mr. William T. Cheesman, Nottingham.
Mrs. William T. Cheesman, Nottingham.
Mr. Frederick Cleeves, London.
Mr. Albert Ladd Colby, New York.
Mrs. Albert Ladd Colby, New York,
Mr. David Colville, Motherwell.
Mrs. David Colville, Motherwell.
Mr. E. G. Constantine, Motherwell.
Mrs. E. G. Constantine, Motherwell.
Mr. Joseph Cook, Alfreton.
Mr. Thomas Cook, Sheffield.
Mr. Arthur Cooper, Middlesbrough.
Mrs. Arthur Cooper, Middlesbrough.
Mr. Joseph Cooper, Jarrow-on-Tyne.
Mr. Edwin Cottam, Cardiff.
Mrs. Edwin Cottam, Cardiff.
Mr. John Cowan, Edinburgh.
Mr. Sherard O. Cowper-Coles, London.
Mr. Thomas Flewett Craddock, London.
Mrs. T. F. Craddock, London.
Mr. T. I. Crane, Philadelphia, Pa.
Mrs. T. I. Crane, Philadelphia, Pa.
Mr. W. H. Crawford, Nashville, Tenn.
Mr. T. Crompton, Ashton, near Wigan.
Mrs. T. Crompton, Ashton, near Wigan.
Mr. Walter Crooke, Jr., Middlesbrough.
Mrs. Walter Crooke, Jr., Middlesbrough.
Mr. J. F. L. Crosland, Hale, Cheshire.
Mr. John Crum, Stoke-on-Trent.
Mr. P. N. Cunningham, Glasgow.
Miss Cunningham, Glasgow.
Mr. Jos. C. Custodis, London.
Mr. Edgar Llewellyn Daniel, Swansea.
Mr. Thos. Danks, Jr., Barrow-in-Furness.
Mr. John Henry Darby, Brymbo.
Mrs. John Henry Darby, Brymbo.
Mr. Frank Davenport, Eccles.
Miss Davenport, Eccles.
Mr. George M. Davidson, Chicago, Ill.
Mrs. George M. Davidson, Chicago, Ill.
Mr. John Cecil Davies, Gowerton.
Mr. John Prosser Davies, Dowlais.
Mrs. J. P. Davies, Dowlais.
Mr. W. H. Davies, Stoke-on-Trent.
Miss Delane, Llangennech.
Mr. Carl Dellwik, London.
Mrs. Carl Dellwik, London.
Mr. T. J. Denny, Paris, France.
Mrs. T. J. Denny, Paris, France.
His Grace, The Duke of Devonshire.
Mr. John Henry Dewhurst, Sheffield.
Mrs. John Henry Dewhurst, Sheffield.
Mr. Edward Dickinson, Sheffield.
Mrs. Edward Dickinson, Sheffield.
Mr. John Dickson, Grosmont.
Mr. Charles E. Dinkey, Braddock, Pa.
Mrs. Charles E. Dinkey, Braddock, Pa.
Mr. Walter Dixon, Glasgow.
Mrs. Walter Dixon, Glasgow.
Mr. William Henry Dixon, Sheffield.
Mrs. H. E. Dixon, Sheffield.
Mr. Thomas E. Dodgson, Rotherham.
Mrs. Thomas E. Dodgson, Rotherham.
Mr. W. H. Donner, Pittsburg, Pa.

Mr. Charles P. Douglas, Darlington.
Mr. Nicholas Downing, Stockton-Tees.
Mrs. Nicholas Downing, Stockton-Tees.
Mr. Francis Drake, London.
Mr. Edward James Duff, Liverpool.
Mr. George Robert Dunell, London.
Mrs. George Robert Dunell, London.
Mr. G. H. Dunn, Dudley.
Mrs. Ruth Dunn, Dudley.
Mr. J. T. Dunn, Newcastle-on-Tyne.
Mr. James Dunnachie, Coatbridge, N. B.
Mrs. James Dunnachie, Coatbridge, N. B.
Mr. Theodore Dwight, New York, N. Y.
Miss M. A. Eames, Merthyr Tydfil.
Prof. J. von Ehrenwerth, Leoben.
Mr. Gustaf Ekman, Morgardshammar.
Mr. Arthur D. Ellis, Bradford.
Mr. James W. Ellsworth, New York.
Mr. Alfred Etchells, Manchester.
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Mrs. F. T. J. Wheeler, Dewsbury.
Mr. Alfred M. While, Sheffield.
Mrs. Alfred M. While, Sheffield.
Mr. J. Morgan While, Furness Abbey.
Mrs. J. Morgan While, Furness Abbey.
Mr. Chas. H. White, Cambridge, Mass.
Mr. G. H. White, Swansea.
Mr. Robert Whitehead, Buxton.
Mr. Benjamin Whitehouse, Dudley.
Mr. Ralph C. V. Whitfield, Eaglescliffe.
Mr. S. Whitmore, Newport, Mon.
Mrs. S. Whitmore, Newport, Mon.
Mr. W. Whitwell, Saltburn.
Mr. John H. Widdowson, Manchester.
Mrs. John H. Widdowson, Manchester.
Miss Widdowson, Manchester.
Mr. R. Murray Wight, London.
Mrs. R. Murray Wight, London.
Mr. George T. Wildsmith, Lincoln.
Mrs. George T. Wildsmith, Lincoln.
Mr. Thos. Wilkinson, Sheffield.
Mr. F. Ainsworth Willcox, Sunderland.
Mr. G. B. Willey, Sheffield.
Mr. Thomas Williams, West Hartlepool.
Mr. R. Williamson, Cockermouth.
Mrs. R. Williamson, Cockermouth.
Mr. Newton R. Wilson, Monterey, Mex.
Mrs. Newton R. Wilson, Monterey, Mex.
Mr. G. P. Wincott, Sheffield.
Sir Lloyd Wise, London.
Lady Wise, London.
Mr. Zung Tse Kien Woo, Yorks.
Mr. Daniel Wood, Chorlton-cum-Hardy.
Mr. John Wood, Wigan.
Mr. Percy Wood, Barnes.
Mr. Reginald N. Wood, Stafford.
Mr. Walter Wood, Philadelphia, Pa.
Mr. William W. Wood, Jr., Sheffield.
Mr. R. G. Woodward, Sheffield.
Mr. John Wortley, Sheffield.
Mr. John D. Wragg, Burton-on-Trent.
Mr. Ernest Alfred Wraight, London.
Prof. Dr. F. Wüst, Aix-la-Chapelle.
Mr. William Wylie, Coatbridge.
Mr. J. B. Wyne, Anhalt, Germany.
Mr. James Young, London.
Miss Young, London.
Mr. Septimus Young, London.
Mr. James E. York, Brooklyn.
Mrs. James E. York, Brooklyn.
Mr. H. P. York, Brooklyn.

SPECIAL EXCURSION TO GERMANY.

Members and Guests Registered at Düsseldorf.

American, English and Others, except German.

Mr. John F. Andersen, Stockholm.
Mr. George D. Barron, Rye, N. Y.
Mrs. George D. Barron, Rye, N. Y.
Miss Dorothy Barron, Rye, N. Y.
Miss M. Elena Barron, Rye, N. Y.
Prof. H. Bauerman, London.
Mr. E. Bernheim, Pittsburg, Pa.
Miss Bliss, New York, N. Y.
Mr. V. M. Braschi, Mexico City, Mex.
Mrs. V. M. Braschi, Mexico City, Mex.
Mr. A. E. Carlton, New York, N. Y.
Mrs. A. E. Carlton, New York, N. Y.
Mr. Charles Catlett, Staunton, Va.
Mr. H. S. Chamberlain, Chattanooga.
Mrs. H. S. Chamberlain, Chattanooga.
Mr. Albert Ladd Colby, New York.
Mrs. Albert Ladd Colby, New York.
Mr. George M. Davidson, Chicago, Ill.
Mrs. George M. Davidson, Chicago, Ill.
Mr. W. H. Donner, Pittsburg, Pa.
Mr. Theodore Dwight, New York, N.Y.
Mr. B. F. Fackenthal, Easton, Pa.
Mrs. B. F. Fackenthal, Easton, Pa.
Mr. C. Fera, Savona.
Mrs. C. Fera, Savona.
Mr. S. Fera, Savona.
Mr. John S. Grasty, Staunton, Va.
Mr. Joseph Hartshorne, Pottstown, Pa.
Mr. Max Heberlein, Mainz, Germany.
Mr. A. Hennin, Porto Ferrajo, Elba.
Miss Alice W. Hill, Bridgeton, N. J.
Mr. Robert W. Hunt, Chicago, Ill.
Mrs. Robert W. Hunt, Chicago, Ill.
Mr. H. Hunter, South Kensington, Eng.
Mr. E. S. Hutchinson, Newton, Pa.
Mrs. E. S. Hutchinson, Newton, Pa.
Mr. George N. Jeppson, Worcester, Mass.
Mr. Julian Kennedy, Pittsburg, Pa.
Mrs. Julian Kennedy, Pittsburg, Pa.
Mr. Reid Kennedy, Pittsburg, Pa.
Mrs. Reid Kennedy, Pittsburg, Pa.
Prof. William E. Kent, Syracuse, N. Y.
Mrs. William E. Kent, Syracuse, N. Y.
Miss Agnes S. Kent, Syracuse, N. Y.
Mr. Paul S. King, New York, N. Y.
Mr. Charles Kirchhoff, New York, N.Y.
Miss Linda Kirchhoff, New York, N.Y.
Mr. J. Henry Lee, Baltimore, Md
Mrs. J. Henry Lee, Baltimore, Md.
Mr. E. J. McCaustland, Ithaca, N. Y.
Mr. C. McCrery, Birmingham, Ala.
Mr. George Mesta, Pittsburg, Pa.
Mr. R. H. Norton, Los Angeles, Cal.
Mrs. R. H. Norton, Los Angeles, Cal.
Miss V. R. Norton, Los Angeles, Cal.
Mr. Paul R. Norton, Los Angeles, Cal.
Mr. R. E. Palmer, London, England.
Mrs. R. E. Palmer, London, England.
Mr. P. C. Patterson, Pittsburg, Pa.
Dr. H. Pauli, Düsseldorf, Germany.
Mr. Richard Peters, Philadelphia, Pa.
Mrs. Richard Peters, Philadelphia, Pa.
Dr. R. W. Raymond, New York, N. Y.
Miss Raymond, New York, N. Y.
Mr. Charles Rhodes, Auckland, N. Z.
Mrs. Charles Rhodes, Auckland, N. Z.
Miss Rhodes, Auckland, N. Z.
Mr. James P. Roe, Pottstown, Pa.
Mrs. James P. Roe, Pottstown, Pa.
Miss Josephine Roe, Pottstown, Pa.
Miss Nancy Roe, Pottstown, Pa.
Mr. Axel Sahlin, Brussels, Belgium.
Mrs. Axel Sahlin, Brussels, Belgium.
Mr. H. Kilburn Scott, London, Eng.
Mr. J. C. Simpson, Jr., Edinburgh, Scot.
Mr. Edward Skewes, Ontario, Canada.
Mrs. Edward Skewes, Ontario, Canada.
Mr. Oberlin Smith, Bridgeton, N. J.
Mrs. Oberlin Smith, Bridgeton, N. J.
Miss Winifred H. Smith, Bridgeton, N. J.
Mr. E. Gybbon Spilsbury, New York.
Mr. Hugh G. Spilsbury, New York.
Mr. George Steiger, Washington, D. C.
Mr. P. Charteris Stewart, Cairo, Egypt.
Dr. Joseph Struthers, New York, N. Y.
Mr. Knox Taylor, High Bridge, N. J.
Mrs. Knox Taylor, High Bridge, N. J.
Mr. Charles C. Titcomb, New Orleans.
Mr. Harold A. Titcomb, New Orleans.
Prof. Charles E. Wait, Knoxville, Tenn.

Mrs. Charles E. Wait, Knoxville, Tenn.
Mr. Charles E. Wait, Jr., Knoxville.
Miss Louisa Wait, Knoxville, Tenn.
Miss Marie Wait, Knoxville, Tenn.
Mr. Chung Yu Wang, Shanghai, China.
Mr. Chas. H. White, Cambridge, Mass.
Mr. Newton R. Wilson, Monterey, Mex.
Mrs. Newton R. Wilson, Monterey, Mex.
Mr. Walter Wood, Philadelphia, Pa.

German.

A. Annacker, Ruhrort.
Jean Balthazar, Bonn.
Kgl. Baurat Beukenberg, Dortmund.
Dr. W. Beumer, Düsseldorf.
Frau Beumer, Düsseldorf.
Fräulein Beumer, Düsseldorf.
H. Biewend, Rheinau i. Baden.
M. Böcker, Friedenshütte, O.-S.
H. G. Böker, Remscheid.
M. Böker, Remscheid.
Frau Böker, Remscheid.
Dr. Bohny, Gustavsburg b. Mainz.
C. Bornhardt, Kalk b. Köln.
M. Bouché, Düsseldorf.
Frau Bouché, Düsseldorf.
Dr. Brandt, Düsseldorf.
Frau Dr. Brandt, Düsseldorf.
G. Breusing, Düsseldorf.
Frau Breusing, Düsseldorf.
W. Brügmann, Dortmund.
Dr. Carl, Düsseldorf.
B. Clasen, Düsseldorf.
Direktor Coupette, Laar b. Ruhort.
Frau Coupette, Laar b. Ruhrort.
Direktor Dahl, Bruckhausen a. Rh.
Gust. Dammeier, Düsseldorf.
Frau Dammeier, Düsseldorf.
Dir. Dresler, Düsseldorf.
Frau Dresler, Düsseldorf.
Emil Dücker, Düsseldorf.
Carola Dürr, Düsseldorf.
Consul Eager, Elberfeld.
Frau Eager, Elberfeld.
Fr. R. Eichhoff, Remscheid.
Frau Eichhoff, Remscheid.
Otto Elbers, Hagen i. W.
W. Ellingen, Köln-Zollstock.
Frau Ellingen, Köln-Zollstock.
Dr. Fahrenhorst, Laar b. Ruhrort.
Frau Dr. Fahrenhorst, Laar b. Ruhrort.
A. Feldhüsen, Essen a. d. Ruhr.
Alb. Fischer, Mühlheim a. d. Ruhr.
G. Frielinghaus, Essen a. d. Ruhr.
Wilhelm de Fries, Düsseldorf.
Frau de Fries, Düsseldorf.
Fräulein de Fries, Düsseldorf.
W. Funcke, Jr., Hagen i. W.
Dr. Gademann, Grenzhausen, Nassau.
Dr. C. Geiger, Düsseldorf.
Direktor Glatschke, Rheinhausen-Friemersheim.
Kurt Goecke, Duisburg-Meiderich.
Alexander Gouvy, Düsseldorf.
Frau Gouvy, Düsseldorf.
Direktor Graszmann, Dortmund.
Dr. Aug. Haarmann, Osnabrück.
Oskar Halbach, Mülheim a. Rhein.
Otto Hammann, Düsseldorf.
Th. Hanemann, Düsseldorf.
W. Haring, Halle a. d. Saale.
Oberbürgermeister Haumann, Köln.
Walter J. Hilger, Düsseldorf.
Fräulein Mietze Hilger, Düsseldorf.
Dir. Hoos, Duisburg-Meiderich.
Aug. Jaeger, Düsseldorf.
Dr. Johannes, Düsseldorf.
H. Jucho, Dortmund.
G. Kehren, Düsseldorf.
Franz Kindermann, Duisburg.
F. Kintzlé, Rothe Erde b. Aachen.
Robert Klein, Dahlbruch.
Direktor Klönne, Rheinhausen-Friemersheim.
Otto Knaudt, Essen a. d. Ruhr.
Franz J. Kolter, Elisenhütte b. Nassau.
Alb. Kösel, Düsseldorf.
Frau Kösel, Düsseldorf.
Dir. v. Kraewel, Duisberg-Meiderich.
Direktor Krausz, Düsseldorf.
Rud. Kunz, Duisburg-Meiderich.
H. Kutscher, Herne i. W.
Dir. Langheinrich, Rheinh.-Friemersh.
Wm. Laue, Düsseldorf.
Frau Laue, Düsseldorf.
Fräulein Laue, Düsseldorf.
E. Leber, Düsseldorf.
Geh. Lehmann, Düsseldorf.
Richard Lemke, Düsseldorf.

Frau Lemke, Düsseldorf.
C. W. Liebe-Harkort, Düsseldorf.
Peter Lieber, Düsseldorf.
Frau Lieber, Düsseldorf.
Richard Lindenberg, Remscheid.
Frau Lindenberg, Remscheid.
Moritz Lipp, Köln.
Dir. Lipschitz, Düsseldorf.
Ernst Lueg, Düsseldorf.
Frau Lueg, Düsseldorf.
H. Lueg, Düsseldorf.
Frau Lueg, Düsseldorf.
Dr. Fritz W. Lürmann, Berlin.
Oberbürgermeister Marx, Düsseldorf.
Professor W. Mathesius, Berlin.
Dir. Mathies, Dortmund.
Professor Mayer, Aachen.
M. Meier, Differdingen.
Dr. Ernst Menne, Creuzthal i. W.
W. Meyer, Duisburg-Meiderich.
Direktor Müller, Neunkirchen a. d. Saar.
Professor P. Osann, Zellerfeld, Harz.
Dr. H. Pauli, Düsseldorf.
Otto Petersen, Heidelberg.
Director Pöhl, Herne i. W.
Paul Reusch, Sterkrade.
Direktor Richter, Mühlheim a. d. Ruhr.
C. Riensberg, Benrath.
Hugo Sack, Rath b. Düsseldorf.
Frau Sack, Rath b. Düsseldorf.
E. Schaltenbrand, Düsseldorf.
Frau Schaltenbrand, Düsseldorf.
Direktor Scheidtweiler, Oberhausen.
Geh. Kom. E. Schiesz, Düsseldorf.
Frau Schiesz, Düsseldorf.
Fr. Schlueter, Düsseldorf.
Frau Schlueter, Düsseldorf.
Fräulein Schlueter, Düsseldorf.
Paul Schmidt, Hannover.
A. Schneider, Düsseldorf.
J. Schoenawa, Völklingen a. d. Saar.
Direktor Schorr, Herne i. W.
Dr. E. Schrödter, Düsseldorf.
Frau Schrödter, Düsseldorf.
Arthur Siebel, Rath b. Düsseldorf.
Frau Siebel, Rath b. Düsseldorf.
Paul Siebel, Rath b. Düsseldorf.
Walter Siebel, Rath b. Düsseldorf.
Elsbeth Spannagel, Düsseldorf.
Fr. Springorum, Dortmund.
Dr. G. Stauber, Aachen.
C. Störtländer, Hamburg.
Gottfried Stoffers, Düsseldorf.
K. J. Sunström, Stockholm.
Frau Sunström, Stockholm.
Fräulein Taussig, Düsseldorf.
August Thyssen, Mühlheim a. d. Ruhr.
Fritz Thyssen, Mühlheim a. d. Ruhr.
Fräulein Troost, Dahlbruch.
Heinrich Tünnerhoff, Hagen i. W.
Frau Tünnerhoff, Hagen i. W.
Otto Vogel, Düsseldorf.
Dr. Voszen, Rechtsanwalt, Düsseldorf.
Prof. A. Wallichs, Mühlheim a. d. Ruhr.
Professor Dr. H. Wedding, Berlin.
Fräulein Wedding, Berlin.
C. Wegeler, Coblenz.
Dr. Alois Weiskopf, Hanover.
Edmund Wellenstein, Ratingen.
Frau Wellenstein, Ratingen.
Franz Weszel, Ingenieur, Köln.
Professor Dr. F. Wüst, Aachen.
A. Ziegler, Oberhausen.
A. Zollenkopf, Schalke i. W.

EXCURSIONS AND ENTERTAINMENTS.

The office of the London Reception Committee, at 28 Victoria St., was open daily from 10 a.m. to 5 p.m., for the registration of members and guests, the issue of badges, programmes, invitation-cards, etc., and the general information and guidance of inquirers. A post-office and a writing-room completed the manifold facilities offered at these headquarters, and the complicated business was smoothly and accurately transacted by Secretary Brough and his assistant, Mr. Sidney.

I. THE WEEK IN LONDON.

Monday, July 23.

On Monday evening, President and Mrs. Hadfield gave a reception at the Grafton Galleries, which was attended by a large and brilliant company, comprising not only the American guests, and several hundred English members of the Iron and Steel Institute, but also many citizens of London eminent in social, political and scientific circles.

The Grafton picture-galleries, in Grafton St., Bond St., were established in 1891 as the headquarters of the Gallery Club. That club no longer exists; but the rooms are a favorite place for social functions on a large scale.

Tuesday, July 24.

On Tuesday afternoon, separate parties of guests visited the following places:

1. *The National Physical Laboratory*, at Teddington, a south-western suburb of London, visited upon the invitation of Lord Rayleigh, President of the Royal Society. The party was received and conducted through the laboratory by Dr. R. I. Glazebrook, the Director, and subsequently entertained by Mrs. Glazebrook at afternoon tea. Messrs. Matthew Murray and Leslie S. Robertson were the Stewards in charge of this excursion.

This institution was opened in 1901 for the standardization and verification of apparatus used in testing materials; the determination of physical constants; and important physical researches. Under the latter head may be named the work now in progress on the resistance of various construction-materials to impact, wind-pressure, alternating stresses, etc., and many investigations in electricity, thermometry, meteorology, metallurgy, and optics. The buildings cost about £25,000; and the Government grants annually £5,500—a sum smaller than the similar grants of Germany, France and the United States, and smaller than the institution deserves and will doubtless in future receive, in view of the fundamental value of its work.

2. *The London County Council's Electrical Power Station*, at Greenwich. The party, under the guidance of Messrs. P. B. Brown and L. Pendred, went by steamboat on the Thames to Greenwich, where they were received by Mr. A. L. C. Fell, and conducted through the station; after which the party visited the car-sheds at New Cross.

This station is situated on the north side of the Thames, opposite the world-famous Greenwich observatory (the authorities of which, by the way, are said to

be already complaining that this vast generation of electric energy so near the observatory interferes with the accuracy of a part of its work). It supplies power for the County Council tramways, which are rapidly extending throughout London. When fully equipped, it will have cost about £1,000,000, and will furnish 52,000 h.p.

3. *Mercers' Hall, Cheapside.* On the invitation of the Master and Wardens of the Worshipful Company of Mercers (the first of the twelve Great Companies of London), and under the guidance of Messrs. F. W. Harbord and E. F. Law, this party had a most interesting experience.

In the City of London, 76 of the mediæval Guilds or Companies still exist. Once they were self-governing bodies, invested by royal charter with wide power over their members and their respective trades. For many years past, most of them have had little or no functions or relations of that kind—though some have recently shown, through the promotion of trade-exhibitions and trade-schools, a renewed interest in the handicrafts which they formerly controlled. In the main, they are now employed in administering real estate and funds bequeathed to them in past centuries; and the bulk of their income is applied to educational and charitable purposes. Their halls are often magnificent, and always both architecturally and historically interesting.

The records of the Mercers' Company go back to the 11th or 12th century. Its incorporation dates from 1393. Among its former duties was the testing of the weights and measures used by the London merchants. Its hall, which suffered greatly in the Fire of London, was rebuilt in 1672 from designs by Sir Christopher Wren, and restored in 1884; and has been the earliest meeting-place of many of the leading business organizations of London, such as the Council of Trade (the origin of the present Government Board of Trade), the Governors of the Bank of England, and the East India Company, and it is still used by the City and Guilds' Institute for the Promotion of Trade and the Governors of St. Paul's school at Hammersmith (an institution controlled by the Company). It contains many interesting pieces of primitive plate, portraits and other souvenirs, valued at more than £20,000. The present annual income of the Company is variously estimated at from £85,000 to £100,000.

The hall of the Grocers' Company, incorporated in 1345, which was also opened to the party, contains an exceptionally fine collection of plate.

4. *The Hall of the Worshipful Company of Armourers and Brasiers*, Coleman St., E. C. This party, upon the invitation of the Master and Wardens, and under the guidance of Mr. J. Dewrance, inspected the rooms of the Company, and was afterwards entertained at afternoon tea in the Court Dining-Room.

In addition to the remarks made above concerning the Guilds of London, it may be here added that the Armourers and Brasiers, previously separate, were merged in 1708. The rooms of the Company are extremely handsome, and include among their adornments many fine examples of the armourer's craft, and

some highly interesting pictures, manuscripts, and plate, valued at about £12,000. The Company has an annual revenue of about £9,500.

On Tuesday evening, a reception was given by the Lord Mayor of London and the Lady Mayoress, at the Mansion House. It goes without saying that this was a most brilliant affair. Such entertainments are among the recognized functions of the Lord Mayor of London; and the spacious apartments of his palace, the Mansion House, are admirably adapted for that purpose. The genial personality of Sir Walter Vaughan Morgan, the present Lord Mayor, and the Lady Mayoress, completed the pleasure of the occasion.

The Lord Mayor of London is chosen from among the Aldermen to serve for one year, beginning with the 9th of November. During this period, his official residence is the Mansion House.

It is scarcely necessary to say that the ancient City of London constitutes but a small part of the metropolis, yet retains most of its municipal powers, though some are exercised by or in conjunction with other authorities. It enjoys also certain special privileges. For instance, the King of England must still have the permission of the Lord Mayor, if he would enter the precincts of "the city." (On every such occasion, the Lord Mayor, having been previously notified of the royal intention, clothes himself in full official regalia, meets the King at the boundary-line, and tenders to him a key, of which the corresponding lock is, perhaps, lost. This key having been courteously touched and returned by the Sovereign, the Lord Mayor spectacularly goes home, and the King goes "whither him liketh." Sir Walter frankly said to an American inquirer that he had never had, and did not expect to have, any occasion to refuse this courtesy; but he evidently considered the ceremony worthy of perpetuation, in witness of the immemorial rights of the City!)

The reception at the Mansion House, as well as other hospitalities, emphasized the fact that not only the Iron and Steel Institute and numerous residents of the metropolis, but also, and particularly, the ancient City of London itself was to be regarded as a welcoming host by the American visitors.

Wednesday, July 25.

On Wednesday afternoon, the following places were severally visited, according to the individual option of guests:

1. *The Works of John I. Thornycroft & Co., Ltd.*, at Chiswick, were visited under the guidance of Sir W. Lloyd Wise and Mr. L. Levy.

These famous works are now chiefly devoted to marine and motor engines. The firm has another establishment at Southampton; and the business comprises the construction of steam-launches, screw-propellors, water-tube boilers, petrol-driven vehicles, and torpedo-boats and destroyers. The number of men employed at the Chiswick works varies from about 1,200 to 1,800.

Sir John Thornycroft himself, who first achieved fame in 1858 as the designer and builder of the steam-launch *Nautilus*, and who subsequently invented the Thornycroft screw-propellor, double rudder, screw-turbine for shallow draft, and water-tube boiler, still retains both physical and mental vigor, and received in person the company of more than 100 visitors. A fleet of the new type of coasting-destroyers was seen on the stocks, as well as many motor-boats; and the making of water-tube boilers was inspected with much interest. A collation was served, at which a vote of thanks to the firm, proposed by Sir W. Lloyd Wise and seconded by Mr. Walter Wood of Philadelphia, Councilor A.I.M.E., was acknowledged by Sir John Thornycroft.

2. *The Works of J. & E. Hall, Ltd.*, manufacturers of refrigerating-apparatus, at Dartford, Kent, were also opened to the inspection of visitors. Messrs. F. A. Willcox and George Schultz were in charge of this party.

This firm was founded in 1785 by John Hall, and after his death, in 1836, the business was carried on by his sons. Edward Hall, the last of the name, died in 1875. The present corporation dates from 1900.

John Hall, Sr., acquired in his day a world-wide reputation as a manufacturer of mills for the making of gunpowder, paper, and other products. Among the early steam-engines, his beam-engine with "Elephant" boiler was a leading type; and so common did it become in France that the "Elephant" acquired the name of "the French" boiler.

The firm first became connected with refrigeration in 1878, when it began to make the Giffard cold-air machine for preserving meat, etc. In 1888 it brought out the carbonic anhydride machine, with which it has since been identified, and to the manufacture of which it is now almost exclusively devoted.

The works comprise iron and brass foundries, pattern, carpenters', machine, brass-finishers', blacksmiths', coppersmiths', coil-making, casing and erecting shops—the latter being so planned as to permit the actual operation of machines, after erection, and the accurate measurement of their refrigerating-capacity. Admirable special tools are employed in sundry departments. All machinery is driven by electric power, generated in the company's power-house by two Willans & Robinson engines, coupled to E. C. 220-kw. dynamos. It is a highly interesting and suggestive circumstance that, about three years ago, the metric system of weights and measures was introduced throughout these works. No doubt the desire to suit foreign buyers was a main reason, and the construction of an immense new plant furnished a favorable opportunity for this change of standards. The significant thing is, that the result has proved highly advantageous, and especially that no difficulty has been experienced by the company's workmen in adopting the new system and adapting themselves to it.

3. *The Inns of Court.* A party conducted by Mr. Pendred, Editor of the *Engineer*, visited (by invitation of the Benchers) the gardens and halls of the Inner and Middle Temples, the Law Courts, and Lincoln's Inn and Hall. The party assembled in the Temple church, where Sir Henry Lawrence, Treasurer of the Temple, before kindly assuming the duties of guide, gave

an interesting historical summary. The various buildings were then visited, the last stop being made at the new hall of Lincoln's Inn, which contains Watts's large fresco representing a cycle of great law-givers, and some fine paintings by Reynolds, Lawrence and Gainsborough. Here a number of old books and manuscripts were shown by the Librarian.

It would be impracticable even to outline here the history of the buildings and gardens of the Temple, from the time when they became in 1184 the headquarters of the Knights Templars, through the suppression of that order in the 14th century and the subsequent transfer of the property to successive noble owners, and finally to the Crown. At present, the four Inns (Gray's, Lincoln's and the two Temples) constitute an exclusive trades-union, possessing the sole right of admitting candidates to the profession of Barrister, with the privilege of practicing in the Law Courts. The Norman and Early English church and the beautiful Elizabethan hall of the Middle Temple are architecturally the most interesting features.

4. *Kensington.* Visits were organized for the Victoria and Albert Museum, South Kensington, the Natural History Museum, the Imperial Institute, the Albert Hall and Kensington Palace, with tea in Kensington Gardens.

Most of these places are too well known to require description here. The Imperial Institute is the most recent of the list in date of origin, having been founded in 1886, under the full title of "The Imperial Institute of the United Kingdom, the Colonies and India, and the Isles of the British Seas," to commemorate the Jubilee of Queen Victoria, who formally opened it in 1893. It is a center of information and an illustrative-exhibition concerning the resources, industries and products of the British Empire. A part of its splendid building is now occupied by the University of London, the Imperial Institute needing at present only the western wing.

5. *The Testing-Station of the British Fire-Prevention Committee,* at 6 North Bank, Hanover Gate, was visited by a considerable number, to witness the test of a reinforced-concrete floor.

The rapid increase, on both sides of the Atlantic, in the employment of concrete as a material of construction, is amply justified by the testimony of experience; and the special qualities of "reinforced" concrete, emphasized by the behavior of this material in the recent San Francisco earthquake, are now appealing very strongly to constructing-engineers of all countries. The opportunity afforded by this invitation was therefore most welcome to many.

On Wednesday evening, the Chairman and Directors of the Imperial-Royal Austrian Exhibition at Earl's Court entertained the members and guests of the two Institutes. The Western

Gardens were specially illuminated, and a programme of American music was given by the orchestra.

Thursday, July 26.

On Thursday afternoon, the following places were visited by separate parties:

1. *The Works of Fraser & Chalmers, Ltd.*, at Erith, Kent. This excursion, comprising about 200 persons, was tendered jointly by the company and the Institution of Mining and Metallurgy, the latter furnishing also a special railway-train for the party. On arrival at Erith, luncheon was served in a marquee erected for the purpose, Mr. Arthur C. Claudet, President of the Institution of Mining and Metallurgy, presiding, and, at the close of the feast, extending to the American guests a cordial welcome, which was appropriately acknowledged by Mr. Charles Kirchhoff, past-President of the American Institute of Mining Engineers.

The visitors were conducted through the shops by Messrs. McDermott (managing director), Sandon (general manager), Whitman (chief engineer), Nicoll (superintendent) and other members of the staff.

These works are peculiarly interesting to American engineers, as the outgrowth of a business first established at Chicago, and long and widely known as a pioneer in the manufacture of modern mining and metallurgical machinery. The demand for such machinery in the British colonies led to the erection of the works at Erith, which, begun in 1892, are now the largest of their class in Great Britain, occupying 17.8 acres, of which 6.5 are covered by buildings. In 1901, the American works were sold, and the business is now centered here. Among the specialties of this establishment are driving-engines, compound hoisting-engines, Whiting hoists, Riedler and Gutermuth pumps and compressors, crushers, stamp-mills, grinding-pans, tube-mills, cyanide-plants, concentration-mills, Wilfley tables and slimers, Frue-vanners, smelting-furnaces, Bessemer converter-plants, roasting-furnaces, Blaisdell excavators, continuous filters, coal-screening and washing plants, boilers, Rateau steam-turbines, Rateau centrifugal pumps and turbo-compressors, ventilator-fans, diamond-washing plants, heavy American types of gold-dredges, and the necessary accessories for the various plants.

2. *Works of the Associated Portland Cement Manufacturers* (1900), *Ltd.*, Northfleet, Kent. This party, under the guidance of Mr. H. Kelway-Bamber, was shown through the works, and afterwards hosptably entertained at the universal and agreeable British ceremony of afternoon tea by the Company.

This corporation is an amalgamation of 22 firms in the Thames and Medway valleys. The works cover an aggregate of 4,000 acres; the river-frontage, with docks and wharves, is more than 9 miles; 200 vessels compose the fleet for transporting materials and products; and the productive capacity per annum is 3,000-000 barrels of cement, most of which is exported.

The Iron and Coal Trades Review of July 27, 1906, after quoting the opinion of a well-known London engineer, that the two most important inventions of the 19th century were Bessemer steel and Portland cement, which had done more than anything else to revolutionize constructional methods, justly adds that the combination of these two materials as "reinforced" or "ferro"-concrete, bids fair to make that revolution more complete than anybody had anticipated. The recognition of this fact by engineers is reflected in the rapid increase of the cement-industry in all civilized countries.

Portland cement is a British invention; and Northfleet may fairly be called the cradle of the industry, as it is the home of its greatest developments. The district is favored with ample supplies of excellent raw material, cheap fuel, and facilities of transportation to all parts of the world.

The consolidation of separate properties and works, in 1900, which created the present company, brought together plants of all degrees of technical perfection; and the modern features of mechanical progress in this industry will be found here and there in the vast aggregate, rather than grouped in a single model plant. Among these may be named the rotary kiln, invented in England, but perfected in America, and now returning victoriously to the country which once rejected it, and bringing, as a necessary concomitant, a new process of continuous manufacture.

Of course, the formation of this consolidated company has effected large economies in the details of operation. Central foundries and machine-shops take care of heavy repairs and new constructions; large factories manufacture barrels by the million; and trained experts prosecute experiments, on a large scale and without intermission, for the discovery and test of improvements in method or machinery. The largest plants in operation are at Northfleet, Swanscombe and Gray's on the Thames, and at Rochester, Halling and Burham on the Medway. The employees of the company number 6,000 or more; and the annual capacity of production will shortly reach 1,500,000 tons of cement.

3. *The Chelsea Power-Station of the Underground Electric Railways Co., Ltd.* The party, conducted by Messrs. P. B. Brown and L. Pendred, was received at the station, and guided in the inspection of it by Chief Engineer Chapman and Mr. Towle.

This magnificent station is in many respects a model of engineering construction and arrangements for the saving of manual labor, as well as of electrical efficiency. It occupies 3.67 acres and is built on a self-supporting steel frame weighing about 6,000 tons. There are 64 water-tube boilers arranged two stories high, and floor-space is provided for 16 additional boilers. Each boiler has 5,212 sq. ft. of heating-surface and 672 sq. ft. of superheating-surface, and is equipped with chain-grate stokers. Each main generating-set consists of a horizontal turbine-engine running at 1,000 rev. per min., and a three-phase generator wound for 11,000 volts, 33⅓ cycles. There are eight such sets, with floor-space for two more of the same size and one of half-size. The normal rating of each generator is 5,500 kw.; but they will carry an overload of 50 per cent. for two hours at

practically the same steam-consumption per kilowatt-hour. The coal-storage capacity of the bunkers is 15,000 tons, and the daily consumption will reach 800 tons.

Coal is received, unloaded, transported, stored and fed to the furnaces by an ingenious system of traveling-cranes, inclined elevators, belt-conveyors, and mechanical chargers; and ashes are removed by a railway, with a storage-battery locomotive. When completed, the station will have a total capacity of nearly 80,000 b.h.p. (at present, the capacity is something less than 60,000 b.h.p.), with a considerable margin for overloading.

4. *The Hall of the Worshipful Company of Ironmongers.*—A party of about 150 (largely ladies), under the guidance of Mr. A. J. Meyjes, was received by the Master and Wardens of the Company in full robes of office, and conducted to the banqueting-hall, where the plate of the company was displayed, and the Honorary Librarian, Mr. E. A. Nichols, gave a brief account of this Guild. After inspecting the plate and other historical treasures, as well as the splendid reception-rooms, the company was entertained at afternoon tea, at the close of which a suitable address of thanks was made by President Hunt, A.I.M.E., and appropriately acknowledged by the Master of the Company.

The origin of this Guild is lost in antiquity. In 1300, the "ironmongers" or "feroners" seem to have controlled the sale of iron in London. In 1351, under Edward III., they were a recognized Guild; in 1463 (Edward IV.) they received a Royal Charter, having already bought in 1457 the site of this present building. Their first hall lasted until 1587; the second (which was injured in the great fire of 1666) until 1745, when the present hall was begun. The splendid banqueting-room, 70 by 29 ft. in size, has a paneled dado, 8 ft. high, bearing the arms of the past Masters since 1351. Twenty Lord Mayors have been members of this Company. The Ironmongers have a fine collection of plate, although the Company was despoiled by Charles II. through a fine so severe as to necessitate the sale of all the plate it then owned (1668).

On Thursday evening, a brilliant *fête* was given at the Crystal Palace at Sydenham, including a dinner at which between 600 and 700 guests were present, and a special display of magnificent fireworks.

Friday, July 27.

At about noon, the King received a deputation, consisting of five officers of the Iron and Steel Institute (namely, Mr. R. A. Hadfield, President; Sir Hugh Bell, President-elect; Sir James Kitson, M.P., senior past-President; Mr. Victor Cavendish, M.P., Vice-President; and Mr. Bennett H. Brough, Secretary)

and eight representatives of the American Institute of Mining Engineers (namely, Messrs. Robert W. Hunt, President; Charles Kirchhoff, past-President; B. F. Fackenthal, Jr., past-Vice-President; Walter Wood, Joseph Hartshorne and Theodore Dwight, Councilors; R. W. Raymond, Secretary, and Oberlin Smith, member of the Institute and past-President of the American Society of Mechanical Engineers). This deputation was received at Buckingham Palace by Sir Maurice Holtzman, Lord Granville and Col. Fredericks, and conducted to one of the state apartments on the first floor, which was shortly after entered by the King. President Hadfield presented the members of the deputation to his Majesty, who shook hands with each, and expressed his pleasure in welcoming the American visitors. President Hadfield then read a brief address, accompanying the presentation of the Bessemer gold medal, which the King acknowledged with similar brevity, but evident cordiality. After a few informal and friendly words, his Majesty bade the visitors "good-afternoon," and retired.

The Bessemer gold medal, instituted by Sir Henry Bessemer in 1874, to be annually given by the Council of the Iron and Steel Institute, as an award for eminent services (through inventions, worthy contributions or otherwise) to the manufacture of iron or steel, has been bestowed as follows:

1874. Sir Lowthian Bell, Bart., F.R.S.
1875. Sir C. William Siemens, F.R.S.
1876. Robert Forester Mushet.
1877. John Percy, M.D., F.R.S.
1878. Peter Ritter von Tunner.
1879. Peter Cooper.
1880. Sir Joseph Whitworth, Bart.
1881. William Menelaus.
1882. Alexander Lyman Holley.
1883. George James Snelus, F.R.S.
Sidney Gilchrist Thomas.
1884. Edward Windsor Richards.
Edward Pritchard Martin.
1885. Richard Akerman.
1886. Edward Williams.
1887. James Riley.
1888. Daniel Adamson.
1889. John Devonshire Ellis.
Henri Schneider.
1890. William Daniel Allen.
Hon. Abram S. Hewitt.
1891. The Right Hon. Lord Armstrong, C.B., F.R.S.
1892. Arthur Cooper.
1893. John Fritz.
1894. John Gjers.
1895. Henry Marion Howe.
1896. Hermann Wedding.
1897. Sir Frederick A. Abel, Bart., K.C.B., F.R.S.
1898. Richard Price-Williams.
1899. Queen Victoria.
1900. Henri de Wendel.
1901. John Edward Stead.
1902. Friedrich Alfred Krupp.
1903. Sir James Kitson, Bart.
1904. Andrew Carnegie.
1905. John Oliver Arnold.

King Edward VII., while Prince of Wales, stood at the head of the list of the Honorary Members of the Iron and Steel Institute, and, since he came to the throne,

has permitted his name to be continued on the catalogue as Patron—a term which he has fairly deserved by his continuous and intelligent interest in the success of the society and of the industry which it represents. The address which accompanied the presentation of the Bessemer medal to him was beautifully illuminated on vellum, the border showing the lions of England, the Tudor rose, a blacksmith's shop, the Scottish thistle, the Scottish lion, the Irish harp, a shamrock, a chain-maker's shop, the Welsh leek and the Welsh dragon. It was worded as follows:

To

THE KING'S MOST EXCELLENT MAJESTY.

MAY IT PLEASE YOUR MAJESTY.

WE, THE PRESIDENT, COUNCIL, AND MEMBERS OF

THE IRON AND STEEL INSTITUTE,

beg leave to approach your Majesty with sentiments of dutiful loyalty and to request your Majesty to honour the Institute by accepting the Bessemer Gold Medal, instituted in 1874 for award for conspicuous eminence in the iron and steel industries, as a slight indication of our appreciation of the warm interest your Majesty has shown as Honourary Member of the Iron and Steel Institute, and, since your Majesty's accession to the Throne, as Patron, in those industries, upon which the prosperity of your Majesty's dominions so largely depends.

Sealed with the Seal of the Iron and Steel Institute this 24th day of July, 1906, in the presence of

BENNETT H. BROUGH, *Secretary.* R. A. HADFIELD, *President.*

The principal general entertainment offered on Friday was the excursion to Windsor, in which nearly 600 ladies and gentlemen took part, under the guidance of Messrs. F. W. Harbord and G. R. Drennell. The party was specially permitted to see much more than is shown to ordinary visitors, including practically all the state apartments of the palace (the magnificent furniture having been uncovered for this occasion), the gardens, the tomb of Queen Victoria, St. George's Chapel, the royal stables, etc. After luncheon, the visitors scattered, returning to London at their convenience.

On Friday evening, the annual dinner of the Iron and Steel Institute took place at the Guildhall, which had been offered for this purpose by the corporation of the City of London. This is said to have been the third occasion on which the Guildhall was thus tendered for a non-municipal purpose: the second having been that of the banquet given in 1889 by the Institu-

tion of Civil Engineers in honor of visiting members of the American Society of Mechanical Engineers and the American Institute of Mining Engineers.* The nature of the first occasion referred to is not known to the writer.

President R. A. Hadfield, of the Iron and Steel Institute, occupied the chair, supported on the right by the Lord Mayor of London, and 600 guests were seated at the tables. Toasts were offered as follows:

1. His Majesty the King (Patron of the Iron and Steel Institute, and Bessemer Medalist for 1906).

2. Her Majesty the Queen, their Royal Highnesses the Prince and Princess of Wales, and the members of the Royal Family.

3. The President of the United States of America.

4. The Lord Mayor and Corporation of London (proposed by President Hadfield, and acknowledged by the Rt. Hon. the Lord Mayor of London).

5. The Imperial Forces (proposed by Lord Allerton, and acknowledged for the Army by the Rt. Hon. R. B. Holdane, Secretary of State for War, and for the Navy by Admiral Sir Archibald L. Douglas, K.C.B., Commander-in-Chief at Portsmouth).

6. The Houses of Parliament (proposed by Sir Hugh Bell, Bart., President-Elect of the Iron and Steel Institute, and acknowledged by Lord Stanley of Alderley for the House of Lords, and by Herbert Samuel, Esq., M.P., Under-Secretary of State for Home Affairs.

7. Our American Guests (proposed by the Rt. Hon. Sir James Kitson, Bart., M.P., Senior Past-President of the Iron and Steel Institute, and acknowledged by President Robert W. Hunt, of the American Institute of Mining Engineers).

8. The Iron and Steel Institute (proposed by R. W. Raymond, Ph.D., LL.D., Secretary of the American Institute of Mining Engineers, and acknowledged by President Hadfield, of the Iron and Steel Institute).

The ladies of the party were received by Mrs. President Hadfield in the beautiful twelve-sided Common Council Chamber, and separately entertained at dinner, after which they were

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* See *Transactions of the American Society of Mechanical Engineers*, vol. x., p. 869.

admitted as spectators and auditors to the galleries and balconies of the great hall.

At the close of the banquet, a social reception was held in the magnificent Art Gallery, which contained on this occasion between 200 and 300 paintings, by eminent Flemish and modern Belgian artists, loaned for this purpose by their owners.

The Guildhall of London is the place of all ceremonial functions (including the annual election of the Lord Mayor and the Sheriff) and the center of administration for the city proper, which occupies about one square mile in the heart of the metropolis. The first building on this site, of which little or nothing remains, is attributed to the 12th century. The present porch on the King St. front (an engraving of which adorned the *menu* of this banquet) is a beautiful piece of Gothic architecture, dating from 1430 A.D. The great hall, 155 ft. long and 55 ft. high, was built after the Fire of 1666; but its exquisite open-work Gothic wooden roof and stained-glass windows are modern. It contains marble monuments to Nelson, Wellington, and Pitt, and two mysterious ancient wooden statues of giants, traditionally known as Gog and Magog, and said to represent two survivors of a conquered tribe, who were brought as captives to London, and compelled to stand as warders at the gates of the royal palace.

No attempt was made to report the addresses delivered at this magnificent banquet; and the Secretary has hesitated to make an exception apparently in favor of himself. But perhaps he may be excused upon a plain statement of facts. On October 2, 1890, at the dinner of the Iron and Steel Institute in New York City, Dr. Raymond made an address, concluding with some verses, entitled "Uncle Sam's Welcome," which had the good fortune to please our English visitors. In 1906, President Hadfield, inviting Dr. Raymond to make one of the addresses at the Guildhall banquet, recalled in flattering terms these forgotten rhymes of 16 years before, and expressed a strong desire that the author thereof should include in his Guildhall address "something more of the same kind." In response to this invitation, Dr. Raymond read at the conclusion of his speech in the Guildhall, verses entitled "Sez Jonathan."

Unfortunately, the shape and immense size of that hall made it impossible for any speaker (except the megaphonic official herald who announced each toast in tones not to be ignored and never to be forgotten) to be heard by more than a small part of the assembly. Moreover, the natural (and perfectly proper) fate of an orator who comes after the time when newspaper reporters must hand in their "copy" for the morning papers, is to be classed with those who, in turf-parlance, "also ran." Consequently, Brother Jonathan's message was neither completely heard at the time, nor published immediately thereafter.

Moreover, "Uncle Sam s Message" is out of print, and the author is unable to comply with requests for copies of it, or of its recent supplement. He therefore yields to the request of discreet friends so far as to reprint both productions, with a few words from each address, needed by way of introduction.

Address of 1890.

I say our fathers were your fathers' brothers, in other words your uncles. That is why U. S. stands for Uncle Sam, in view of which significant circumstance I beg to conclude with offering to you

Uncle Sam's Welcome.

I'm glad to see ye! Walk right in!
  Set down and rest, and feel to hum.
Ef thar's one thing that makes me grin,
  It is, to hev good company come.
      Thet's wut *I* am,
      Says Uncle Sam.

I hev my times o' gittin' riled,
  Times when I let my eagle scream:
But ginerally I'm ez mild
  Ez apple-sass, fixed up with cream—
      Meek ez a lamb,
      Says Uncle Sam.

I've got ez quick a hand to shake
  An *open* hand, ez ever you see;
Although I reckon folks don't make
  Much profit shakin' *fists* at me.
      No *ma'am!*
      Says Uncle Sam.

My doors air open all the time
  To free, true men of every name;
But when the bummers' guard of crime
  Brings riot's flag of blood and flame,
      Them doors I'll slam!
      Says Uncle Sam.

My table's big; my eatin's good;
  There's plenty in the pantry, too,
For all the world. In fact, I could
  Export more vittles than I do—
      Especially *ham!*
      Says Uncle Sam.

I've got a continent o' coal
  An' gas—you bet!—just hear it roar,
Thar's stacks to melt, and mills to roll,
  An' trains to haul—an' ez fur *ore*—
      A puffeck jam!
      Says Uncle Sam.

Now don't you mind me ef I brag;
  Thet's jest my way to show I'm proud
To hev ye fetch yer carpet-bag
  An' visit. Ef I speak too loud,
      Why, thet's all flam,
      Says Uncle Sam.

Fur I'm pertickilarly fond
  O' sittin' down to talk an' dine
With brothers from across the pond,
  Whose mother wuz the same ez mine.
      I ain't no *clam*,
      Says Uncle Sam.

I'd like to show ye round my place,
From north to south, from east to west;
But 'tain't no use, into the space
You ingineers have so compressed
Thet job to cram,
Says Uncle Sam.

So make your plans to stop a while;
An' ef you sort o' call to mind,
Thet little transatlantic isle,
Jest send the folks you left behind
This telegram,
Says Uncle Sam.

Don't worry over our delay,
They're goin' to put us through, or bust!
An' ef a few weeks more we stay
Than we intended to, you must
Not care a—bit!
Says Uncle Sam.

Address of 1906.

The American Revolution of the 18th century was no conflict between England and America. It was simply a struggle, in both England and America, between the party of liberty and the party of tyranny, in which liberty simply won its victory on our side, sooner than it did on your side, of the ocean. Your best and greatest men were with us. Even your common people refused to fight against us. It was because, even upon the offered inducement of double pay, Englishmen would not enlist to serve against their American kinsmen, that the British ministry of that day was forced to hire European mercenaries for that repugnant work. Our victory was your victory; our war-cry has long been yours; the principles we then declared are the principles you already cherished, and for which you have since shed English blood.

Sixteen years ago, I spoke in the City of New York to this same toast, "The Iron and Steel Institute," and ventured to express to you "Uncle Sam's Welcome." In view of what I have just said, I dare to offer with confidence to-night "Brother Jonathan's" message:

Sez Jonathan.

Now don't tell me the British Oak
Was *split* by any lightnin' stroke!
Bless your soft head, that wa'n't a *split*,
But just a fork, that doubled it!
For Freedom ain't no sapling slim
A-feared to grow another limb:
Thar's two big branches to that tree,
An' one is *you*, an' one is *me*,
Sez Jonathan, sez he!

Your bough's the biggest up to date;
But mine has struck a lively gait,
An', fust you know, she'll shove her way
Right alongside o' yourn, some day,

While through 'em both, from foot to cap,
Tingles an' climbs the same old sap!
No matter whar them branches be,
Thar ain't but one trunk to that tree!
Sez Jonathan, sez he!

What's more, we're both a-branchin' yet
With every blessed chance we get;
An' every limb that we send out
Is welcome to grow stanch and stout.
The sky above, the sile below,
Give room and food for all to grow,
An' limbs and leaves that flutter free
Jest add more glory to the tree,
Sez Jonathan, sez he!

Grow on, O stalwart oak an' tall!
Spread wide thy branches, great an' small,
While in their shelter nest the birds,
And in their shadow stand the herds!
Lift all thy heads to greet the sun
That crowns with splendor every one!
So men, till men shall cease to be,
May praise and bless the ancient tree,
Sez Jonathan, *say we!*

Saturday, July 28.

The principal excursion for this day was a trip to Dover, to inspect the new harbor-works now in construction at that port. A special train conveyed the party of about 250 ladies and gentlemen, under the charge of Sir Lloyd Wise. On arrival, the guests were conducted over the Admiralty pier, and then taken by steamer to the Promenade pier, and to the Hotel Burlington, where an elegant luncheon was served. Sir Weetman Pearson, M.P., representing the directors of S. Pearson & Son, Ltd., the hosts of the occasion, presided, and expressed the pleasure of the company in receiving the members of two such important societies. Addresses were also made by Mr. E. W. Moir, one of the directors, and President Hunt and Secretary Raymond of the Mining Engineers. This excursion was one of the most delightful and interesting connected with the London meeting.

The piers and breakwaters now under construction will inclose a square mile of water outside the existing commercial harbor of Dover, and form the largest artificial harbor in the world. The south breakwater is 4,200 ft. long, and the western arm 3,320 ft. long, while the old Admiralty pier has been extended a further 2,200 ft., and is now practically finished. Operations began in 1898, and

are to be completed by 1908. A steamboat and a contractors' train were requisitioned to convey the visitors to the most interesting portions of the works, the distances being too great to be traversed on foot. The diving-bell used for excavating was seen at work, as well as divers descending into the water without a bell, to place the submerged concrete blocks. As may be supposed, the consumption of concrete is enormous; and the magnitude of the plant used to mix the materials and produce blocks of uniform size, and the enormous cranes required to move the blocks, excited wonder among all. The blocks ordinarily used weigh 40 tons, and, to give some idea of the colossal character of the contract, it may be added that three millions of them will be used.

A party of about seventy visited on Saturday the works of Thomas Butlin & Co., Ltd., at Wellingborough, to witness the casting of pig-iron direct from the blast-furnace. After the inspection of the works, the party was entertained at luncheon, Mr. W. H. Butlin in the chair, and speeches were made by Mr. Butlin, Hon. Robert J. Wynne (U. S. Consul-General), Prof. H. Bauerman, Mr. J. E. Touche, Mr. E. Saladin, Councilor J. Manfield, Mayor of Northampton, Councilor S. G. Stockford Saville, Chairman of the Borough, Mr. J. S. Jeans, past-Secretary of the Iron and Steel Institute, and Justice Rouse Orlebar, and Mr. Harry Foster.

This establishment has produced during the last two years a large tonnage of tunnel-segments, cast directly from the blast-furnace. It also manufactures pipes, and a wide range of general castings, without the intervention of the cupola.

Another excursion was made on Saturday by a party comprising many eminent engineers and experts, to the works of the South Staffordshire Mond Gas (Power and Heating) Co., at Dudley Port, the inspection of which was greatly facilitated by a preliminary description of the plant, given by Mr. H. A. Humphrey, Consulting Engineer of the company.

According to the statement of the company, this is the first installation erected to supply producer-gas over a large area to consumers requiring power and heat.

The plant was started in February, 1905, and has since run continuously day and night without a single stoppage.

The Mond gas generated at the central station is made from common bituminous fine coal or slack, costing less than $1.50 per ton, from which the ammonia is recovered by Dr. Mond's process. With the average quality of coal obtained in England, the yield of ammonium sulphate is between 80 and 100 lb. per ton of coal gasified, and has a value of about $2.

The station is planned for 4 units of 8 producers each; the first unit only has been erected. Each producer is capable of gasifying 20 tons of coal per day.

The gas is compressed and distributed at a pressure of 5 lb. per sq. in., to be increased later to 10 lb.

Steel pipe of special construction conveys the gas underground, and distributes it over the 120 sq. miles of the company's area. The diameter of the trunk-mains is 36 in., and the longest distance to which the gas has been taken, so far, is 8 miles. The gas is sold to customers at prices varying from 3c. to 5c. per 1,000 cu. ft., according to the quantity taken, and is measured through a new type of rotary meter.

In view of the possible substitution of producer-gas for natural gas in America, and the daily-increasing application of washed producer-gas, from which by-products have been recovered, to the iron and steel industries both for heating and for use in gas-engines, it was hoped that this visit would be of special interest to the American guests.

Sunday, July 29.

On Sunday afternoon, a service was held in St. Paul's cathedral, at which Archdeacon Sinclair preached a sermon with special reference to the American visitors. A party conducted by Mr. E. T. Agius attended service at the Roman Catholic cathedral at Westminster. Others visited the Zoological Gardens, etc.

Badges and Souvenirs.

The badge distributed by the London Reception Committee was a handsome pin, bearing the arms of the City of London. An album, containing 250 views of London, and a Souvenir, prepared by the Iron and Steel Institute (containing portraits of President and Mrs. Hadfield, Secretary Brough, the leading members of the London Reception Committee, the Lord Mayor and the Lady Mayoress of London, and numerous eminent English engineers, together with admirable views of London buildings, etc., and illustrated descriptions of important establishments) were presented to guests, as was also a "Keepsake of London," an exquisite booklet, specially written for the London Reception Committee by Mr. A. C. Meyjes, of the editorial staff of *The Ironmonger*, and beautifully printed and illustrated, which contained descriptions and historical notices of the localities to be specially visited during the week in London. In addition to these gifts, the proprietors of the works visited distributed to their visitors elaborate and valuable souvenirs, containing full information concerning plants, proceedings, etc. It is scarcely necessary to observe that such printed statements are far more valuable and welcome to professional guests than social entertainments or purely ornamental gifts.

Press Reports.

Besides the flattering notices of the daily journals, more or less extended reports of the papers, discussions and excursions were published by many professional and trade journals, including: *The Colliery Guardian*, *Engineering*, *The Engineer*, *The Mining Journal*, *Railway and Commercial Gazette*, *Page's Weekly*, *The Financial News*, *The Ironmonger*, and *The Iron and Coal Trades Review*. To the exceptionally complete and accurate accounts given in the two journals last named, the Secretary is indebted for many particulars embodied in the foregoing sketch.

II. The Northern Trip.

Monday, July 30.

A special train conveyed the party to York, where, after luncheon at the hotel, visits were made to the Cathedral, the Roman remains, the mediæval walls, and the Norman castle.

Meanwhile, a party under the guidance of Mr. W. H. Chambers, Managing Director, visited the Cadeby Main Colliery, via Doncaster and Conisborough, rejoining the rest at York in the evening.

Cadeby Main Colliery lies in the Don valley between Rotherham and Doncaster, near the ancient and historic Conisborough castle, about 5 miles SW. of Doncaster. It belongs to the Denaby & Cadeby Main Collieries, Ltd., and employs about 4,000 men and boys.

There are two shafts, 16 ft. in diameter: No. 1 (downcast; depth, 763 yd.), and No. 2 (upcast; depth, 750 yd.). The winding-engines (practically the same for both) are coupled engines, double-acting, with cylinders 45 in. in diam. by 7 ft. stroke; and steam-pressure, 80 lb. per sq. in. Drums, conical, 21 to 33 ft. diameter, 16 ft. wide. Rope, $1\frac{7}{8}$ in. diameter (about 6 in. circumference), weighing 7 tons 6 cwt. Ormerod's safety-hook is used, and the rope is attached to the cage by patent spring, the weight of cage and spring being 6 tons 13 cwt. The four-decked cages carry two 10-cwt. tubs on each deck, or a total load of 4 tons. Each hoisting (24.75 revolutions) takes 55 seconds; and 5 seconds is required for changing or decking. All the four decks are changed simultaneously by hydraulic machinery. The hydraulic apparatus was designed by Mr. W. H. Chambers. The total quantity of coal hoisted per day of 14 hr. from one shaft is 3,360 tons. The shafts are fitted with steel-rail guides.

The headgears are built of iron and steel lattice, No. 1 being 90 ft. and No. 2 103 ft. high. The pulleys at each shaft are 16 ft. in diameter.

The pit-banks are supported on columns, so that the largest wagons can be run under the screens. During the hoisting in the shaft, the empty hydraulic cage is being loaded with empty tubs; as soon as the cage settles on the "fallers," hydraulic rams push the empty tubs into the cage, at the same time pushing the full tubs out of the winding-cage into the hydraulic cage. By this means all

four decks are loaded and unloaded, surface and underground, simultaneously. The full tubs gravitate from the hydraulic cages to the creepers, and are then raised to the level of the tipples. The empty tubs, after leaving the tipples, return by means of creeper and suitable gradient to the pit-mouth. Each creeper is worked by a 5-h.p. electric motor, running at 570 rev. per min.

There are 14 Lancashire boilers, 7.5 ft. in diameter, the working-pressure being 80 lb. per sq. in.; and 3 of 8.5 ft. diameter, with working-pressure of 120 lb. per sq. in. The latter supply steam for the electrical generators.

Ventilation is effected by a Schiele fan, of 21 ft. diameter, driven by a double-acting engine with single cylinder, diameter 42 in.; stroke, 54 in.; steam-pressure, 80 lb. per sq. in. The driving-wheel, 24 ft. in diameter, weighs 20 tons. The quantity of air is about 180,000 cu. ft. per min. A duplicate fan of the Waddle type, 9 ft. in diameter, is driven by electric power.

There are three coal-washers: the Baum, now in course of erection, the Lührig, and the Humboldt—capacity, 250, 60 and 100 tons per hour, respectively. All the water from the washers is conducted to settling-tanks, and, after some time, is drawn off perfectly clean and used over again. The settlings are removed from the tanks by bucket-elevators into wagons, and conveyed to the boiler-fires for fuel. There are 180 retort-beehive coke-ovens, and 10 patent ovens, 30 ft. long and 6 ft. wide.

All the coal is raised from the Barnsley seam, which has a maximum thickness of 10 ft. The workings are on the pure long-wall method, and all roads are laid out to facilitate the quick handling and dispatch of coal. The coal is brought from the working-faces to the shafts by endless ropes, operated by electric three-phase motors. For secondary haulage, gravitation is utilized, the coal being "jinnied" or "jigged" on to the main roads. The pit-bottoms are fitted with hydraulic decking-arrangements on the same principle as those on the surface.

Very little water is encountered underground. In the pumping-house on the surface there are two motors of 70 h.p., pumping water from bore-holes into reservoirs for the use of the village.

Tuesday, July 31.

The gentlemen of the party left York by special train, provided by the North-Eastern Railway Company, reaching Middlesbrough at 9.45 a.m., where they were received at the Cleveland Club by Sir Hugh Bell, Bart., chairman, and the reception committee (whose names are given on a preceding page), and divided into groups for visiting respectively the works of Bell Brothers, Ltd.; Bolckow, Vaughan & Co., Ltd.; Cargo Fleet Iron Co.; Dorman, Long & Co.; Richardsons, Westgarth & Co., and the North-Eastern Steel Co.

After these visits, the reunited company was entertained at luncheon in the Town Hall of Middlesbrough, where Sir Hugh Bell presided, and offered toasts to the King, the President of the United States, and "Our American Visitors," the latter sentiment being accompanied with an eloquent and humorous

speech by the Chairman, and appropriately acknowledged by President Hunt, A.I.M.E. The toast of "The Trade and Commerce of Tees-side" was offered by Secretary Raymond, A.I.M.E., and responses were made by Sir Thomas Wrightson, Bart., Sir S. A. Sadler and Sir Hugh Gilzean Reed.

A beautifully printed and illustrated volume, on "The Ports of the River Tees," compiled by the Secretary to the Tees Conservancy Commissioners, was presented to each guest, as were also elaborate accounts of the various works visited, from which most of the following data have been extracted.

The improvement of the Tees is a wonderful chapter in the history of modern industrial enterprise. Formerly, there were, from Middlesbrough to the sea, four channels, so tortuous and shifting that several of the principal lights had to be mounted upon rollers and moved to follow the changes of channel. In 1863, the depth of water on the bar was only 3.5 ft. at ordinary low Spring tides. Now it is 20 ft. at low, and 37 ft. at high water. This great change has been effected by the construction of 24 miles of training-walls in the river and estuary—a work which occupied 27 years; by dredging about 26,200,000 cu. yd. from the river-bed; and by the building of the South Gare and North Gare breakwaters: the former over 2.5 miles long, begun in 1863 and finished in 1887, of Portland cement-concrete upon a foundation of slag, and containing nearly 5,000,000 tons of slag and over 18,000 of cement; the latter now 3,330 ft. long, presenting on the sea-face a concrete wall, 12 ft. thick by 26 ft. high. Further improvements are in progress and in contemplation. Incidentally, about 2,800 acres of land have been reclaimed from the "fore-shore" of the Tees.

The result of these operations, accompanied with the construction of a graving-dock, with electric light and power, the wise progressive reduction of all tolls and dues imposed upon shippers, and the liberal inducements offered to new enterprises seeking adequate building-space, has been the development of an immense industry and commerce, based chiefly upon the exploitation of the Cleveland iron-ores, and the salt deposits of the district. The aggregate exports for 7 years (1899 to 1905 inclusive), have been of iron and steel, crude and in manufactured forms, 10,623,503 tons; salt, 922,884 tons; ground basic slag as fertilizer, 533,441 tons; coal, 600,759 tons; and rough slag, cement, clay, bricks, limestone, mill-cinder, ore, etc., 398,113 tons.

Sir Lowthian Bell and his associates were pioneers in this development, as has been picturesquely told in Prof. H. M. Howe's "Biographical Notice of Sir Lowthian Bell, Bart.," *Trans.*, xxxvi., 412.

Bell Brothers, Ltd. The party visiting the Clarence works was conducted by Sir Hugh Bell, Mr. Greville T. Jones (manager), and Mr. W. L. Johnson (director). These works, on the north bank of the Tees, comprise 12 blast-furnaces and a steel-works leased to Messrs. Dorman, Long & Co., Ltd. The 8 furnaces in operation produce 350,000 tons of Cleveland pig-iron per annum. Much of the output goes to the steel-works, and the rest (mostly foundry-iron) to local works in Scotland, various parts of England, most countries on the Continent of Europe, India, Australia, Canada, etc. The iron-ore for the furnaces comes from the company's mines in Cleveland; the coke, partly from its collieries in Durham and partly from by-product ovens erected, in co-operation with a

German firm, at Clarence, where about 2,800 tons per week are now produced; and the limestone, from the company's quarry in Weardale, Durham.

About 5,500 men are employed by the company.

Bolckow, Vaughan & Co., Ltd. The party visiting the Cleveland iron- and steel-works of this company, at Grangetown, near Middlesbrough, were conducted by Messrs. Arthur W. Richards (manager of the works), T. Davies, D. Wilson, G. Bellwood, T. Prosser, W. Anderson, A. Stainsby, J. Webb, and C. Jones. These works, on the south side of the Tees, about 3 miles from Middlesbrough, comprise blast-furnaces, steel-works and iron-mines. There are 25 blast-furnaces in all (20 now in operation), of which 3 are mechanically charged. The total output of all grades of iron is 940,000 tons per annum.

The greater portion of the Cleveland ironstone is brought 2.5 miles, by the company's railway, from its mines at Eston, to the calcining-kilns, the remainder coming from mines near Saltburn. The total output of ironstone from the company's mines is 2,750,000 tons per annum. The hematite is brought by vessels from Spain and other foreign ports, and discharged at the company's wharf, which has a river frontage of about 1,500 ft. The slag is taken from the furnaces in ladles and tipped in a molten state to fill up the fore-shore of the Tees in front of the works.

At the steel-works, the acid and basic Bessemer and the acid and basic open-hearth processes are employed.

There are two 150-ton metal mixers; ten 8- to 15-ton converters; eight 20- to 60-ton open-hearth furnaces; one 48-in. blooming-mill for rails, etc.; one 60-in. slabbing-mill for plates; one rail-mill for ordinary rails from 40 to 100 lb. per yd.; one mill for street tram-rails up to 120 lb. per yd., by 60 feet long, and also for steel sleepers, joists and merchant-sections; one small mill for all sections of fish-plates, light rails, etc., up to 40 lb. per yd.; two plate-mills—one capable of turning out plates from ⅜ to 3 in. thick by 108 in. wide, and the other making plates from ⅛ to 1 in. thick by 84 in. wide.

The majority of the auxiliary machines in the steel- and iron-works are electrically driven by a three-phase alternating-current from the company's power-station. The total output of finished steel is 234,000 tons per annum. The company also owns extensive collieries in the Durham coal-field, about 30 miles from Middlesbrough, the output from which is about 1,750,000 tons per annum. The total number of men employed under the company is about 12,000.

Cargo Fleet Iron Co., Ltd. The party visiting the works of this company at Cargo Fleet, Middlesbrough, was conducted by Managing Director C. J. Bagley and Director Benjamin Talbot. This company controls the London mines, the Mickleton limestone-quarries and the Cargo Fleet iron-works, all of which have been running many years, and are now under extensive reconstruction and re-arrangement, for the creation of a comprehensive and symmetrical modern plant. The original 5 blast-furnaces (24 by 75 ft., blown by a beam-engine at 4 to 5 lb. per sq. in.) have been replaced with two furnaces, 90 ft. high, 11 ft. hearth-diameter, and 21 ft. bosh-diameter, operated by 7 gas single-acting Otto cycle blowing-engines of the Cockerill type, delivering 14,000 cu. ft. of air per min. at 10 to 12 lb. per sq. in., and capable of 17 to 18 lb. when necessary. The gas-cylinders have 51.5 in. diameter; the blowing-cylinders, 59 in. diameter by 55 in. stroke; and the rate of running is 70 to 80 rev. per min.

The gas-washing plant comprises 3 Theisen washers, capable of dealing with the gas (1,800 cu. m. per min.) from both furnaces.

Each furnace has Sahlin's bosh and bronze or copper tuyeres; and a Vaughan

gun, used for plugging the tap-hole while the blast is on the furnace, has been found very satisfactory. It is seldom necessary to take off the blast in order to close the hole after casting.

The coal-washing plant consists of a Humboldt washery, treating 60 tons per hour.

The coke-plant comprises 100 ovens, the gases from which are passed to the by-product plant, where tar and ammonium sulphate are recovered. The gas leaving this plant is still capable of developing 3,000 h.p. in gas-engines.

Iron-ore is obtained from the company's Liverton mines, on the North-Eastern Railway, near Loftus, about 20 miles from Cargo Fleet. The royalty extends over about 2,500 acres; the seam of ironstone varies in thickness from a little over 6 to about 9 ft., and is estimated to contain between 30,000,000 and 40,000,000 tons. The two blast-furnaces require about 7,000 tons per week; and the appliances at the mines have been remodeled to enable this output to be obtained by working only one 8-hr. shift.

The steel-smelting shop contains two 175-ton Talbot furnaces with a third under construction. Gas is supplied by ten Talbot mechanically-stirred producers. On the furnace platform is a Wellman electrically-driven charging-machine. There are two 40-ton hot-metal cranes on the charging side, and a 75-ton steel-casting crane on the casting side. One 150-ton gas-fired mixer is installed, together with the necessary crushing and grinding plants for manganese, pig, dolomite, etc. The producers furnish 150,000 cu. ft. of gas per ton of coal gasified, the average analysis being CO_2, 6.2; CO, 23.6; H, 14.8; CH_4, 3.1; N, 52.3; giving a total of 41.5 per cent. by volume of combustible gas. The calorific power of this gas is 1,458 kilo-calories, giving a flame-temperature of 2,000° C. Ordinary producers yield CO_2, 8.3; CO, 19.9; H, 14.9; CH_4, 2.5; N, 54.5, giving a total of 37.3 combustible gas, the calorific power being 1,294 kilo-calories, and the flame-temperature 1,900° C.

The boiler-plant for supplying steam to these mills consists of 10 Nesdrum and two Lancashire boilers, the boilers being provided with coal-fired grates, and also gas-burners for utilizing the gas left over from the blast-furnaces, which, it is anticipated, will produce one-third of the steam required.

Many interesting additiona particulars were furnished by the company, for which, unfortunately, space cannot be found here. Evidently the reconstruction of these great works has been planned after careful study of existing plants, and with the purpose of including the best modern methods and appliances for the cheap and efficient handling of a large product.

Dorman, Long & Co., Ltd. The party visiting the Britannia works of this company was received by Mr. Alfred M. Mosscrop, the General Manager.

These works, said to be the largest and best-equipped in Great Britain, comprise steel-furnaces, rolling-mills and constructional- and bridge-shops. Basic open-hearth steel is here rolled into all sections required for engineering, shipbuilding and general construction. The output of the constructional-shop is 3,500 tons of finished work per month.

The company presented to each visitor a "Pocket Companion" of 267 pages, handsomely printed, illustrated and bound, and containing useful information and tables pertaining to the use of steel, which had been computed and edited by its constructional department for the use of engineers, architects and builders.

Richardsons, Westgarth & Co., Ltd. Visitors were received at these works by Managing Director Tom Westgarth, Works-Manager Jackson, and his assistant, Mr. Key.

This company's works, near the Middlesbrough station, are devoted to marine and general engineering, boiler-making, etc. They also build steel-works plants, gas-engines of large size, tilting-furnaces, etc. Most of the machinery, including the Talbot furnaces, the cogging- and finishing-mills, with their 18,000 i.h.p. engines, and the complete installation of gas-driven blowing-engines at the Cargo Fleet Co.'s works, were built by this company.

A great variety of work was seen by the party, including marine engines, quarter-crank blowing-engines and gas-engines (one of 1,000 i.h.p. for dynamo-work, to use blast-furnace gas, having two double-acting tandem cylinders, 29.5 in. in diameter by 35.5 in. stroke, to run 120 rev.). Also an engine of 900 i.h.p., to drive a ventilating-fan, using waste gases from patent coke-ovens. This engine has two single-acting cylinders 35.5 in. in diameter by 39.5 in. stroke.

In the boiler-shops were seen marine boilers of about 16 ft. diameter for 180 lb. working-pressure, each weighing about 50 tons; also various other work, including 200-ton Talbot patent tilting-furnaces.

The North-Eastern Steel Co., Ltd. Visitors to these works were received by Messrs. Arthur Cooper, F. W. Cooper, P. S. J. Cooper, Calderwood, Marston and Ridsdale.

These works were built in 1881–3 to make steel from phosphoric pig by the basic process.

The four Acklam blast-furnaces were acquired about 10 years ago, since which time the whole plant has been remodeled. There are three furnaces in blast, making basic iron for use at the steel works, and producing from 1,400 to 1,600 tons each per week. Adjoining the furnaces is a battery of 50 Semet-Solvay coke-ovens with recovery-plant. The iron is brought molten from the furnaces to the two 180-ton mixers. The four 12-ton Bessemer converters produce about 4,000 tons per week.

In connection with the steel works there is also a basic-slag works, making about 1,200 tons of phosphate per week.

While the gentlemen of the party were occupied as above described, a delightful excursion was provided for the ladies to Fountains Abbey, access to which had been kindly granted by the Marquess of Ripon. This entertainment was arranged by Ladies Bell, Ropner, Wrightson and Sadler, Mesdames Williams, Cooper, Westgarth, Amos, Riley, Stead, Dorman and Hedley, and Misses Whitwell, Hedley and Gilzean Reed, of the Tees-side Ladies' Committee. At the luncheon served in the cloisters of the abbey, Lady Bell proposed the health of the American guests, and Mrs. Robert W. Hunt responded. The ladies concerned have declined to furnish detailed reports; but it is understood that the after-dinner oratory of the occasion suffered nothing through the absence of the over-worked official post-prandial speakers of the inferior sex, who, it is safe to say, would have given much to be present—and, for once, simply to listen!

Both parties were re-united in the afternoon at Durham, where they were conducted through the Cathedral, Castle and University by Dr. Kitchin, Dean of Durham, and Dr. H. Gee, Master of University College, and subsequently entertained at afternoon tea in the Hall of the Castle.

The party left Durham in the evening by special train for Newcastle-upon-Tyne.

Wednesday, August 1.

The special trains of July 31 and August 1 were furnished by the courtesy of the North-Eastern Railway Co., and the programme for August 1 and 2 was prepared and carried out by the North of England Institute of Mining and Mechanical Engineers, the Wood Memorial Hall of which society was the Newcastle headquarters for registry, information, etc. On Wednesday morning, at this hall, the party was received by the Lord Mayor (Sir J. Baxter Ellis), the Sheriff (Councilor Johnstone Wallace), President T. W. Benson, Secretary M. Walton Brown, and the members of the Council of the North of England Mining and Mechanical Engineers. After this reception, three alternative excursions took place, as follows:

1. *The River Tyne.* A large number, including many ladies, were conveyed by the Tyne Improvement Commissioners' steamer "J. C. Stevenson" to the Dunston coal-shipping staithes of the North-Eastern Railway, where they were received by Mr. Charles A. Harrison, and spent an hour.

The staithes used for shipping coal in the North of England are elevated jetties, with tipping spouts. The present one at Dunston is parallel to the bank, and has, in a length of 1,709 ft., three ship's berths, each provided with two sets of 4, 5 or 6 spouts, placed 87.5 ft. apart. On the top are three tracks, on a rising grade of 1 : 90, with the necessary switches. On the two inside tracks the loaded cars are pushed by locomotives to the staithe-head, and then transferred to the outside track, on which they return by gravity to be emptied into the shoots in batches of about a dozen. Ordinarily about 40 carloads of 10.5 tons each can be poured down one spout in an hour. The average daily rate, including stoppages, is 4,000 tons per spout.

The new staithes, constructed since 1897, considerably increase the shipping-capacity, and are accompanied with a tidal basin to accommodate waiting colliers.

Passing down the river, under the Redheugh, King Edward and High Level bridges, and through the Swing-bridge, the

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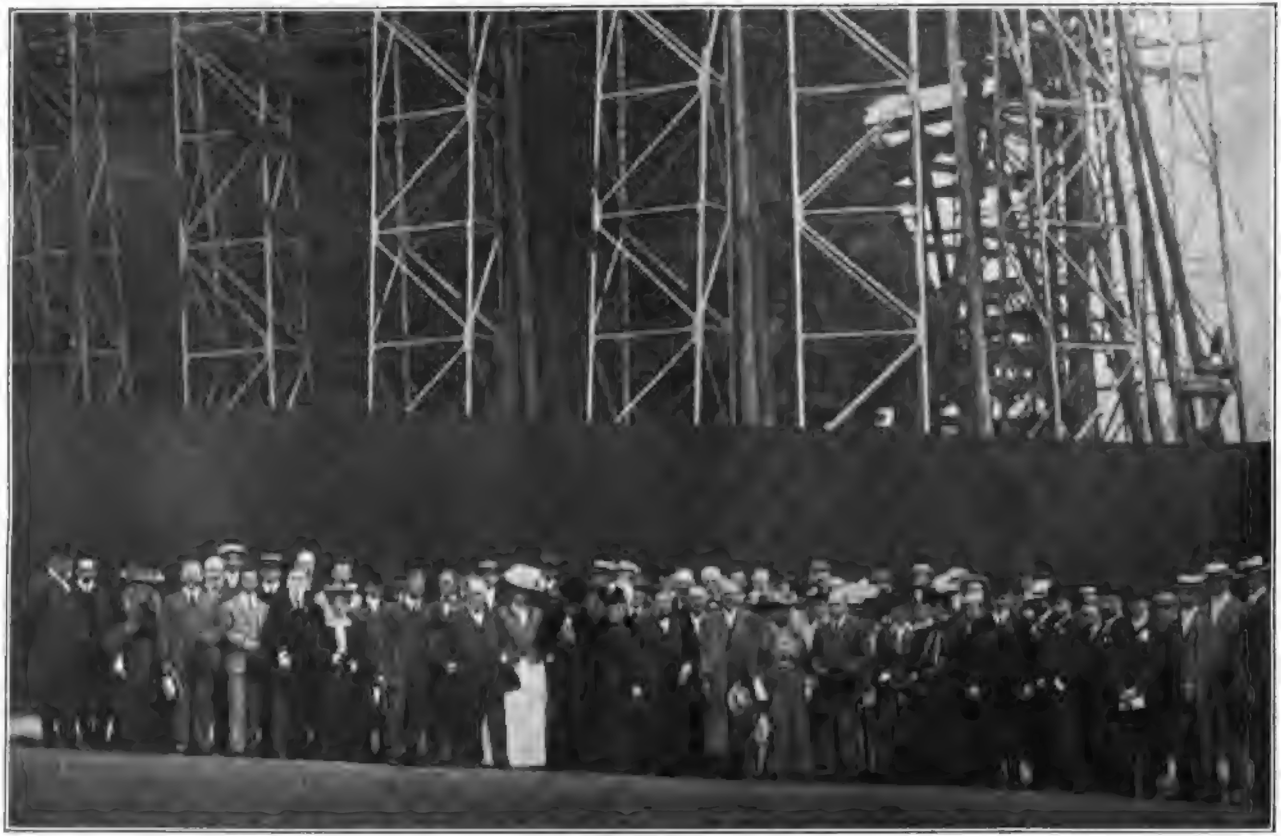

VISIT TO WALKER & WALLSEND WORKS, RIVER TYNE, AUG. 1, 1906.
The structure in the background is the stern of the Cunard turbine SS. "Mauretania."

Excursion on Firth of Clyde, SS. "Duchess of Hamilton," Aug. 3, 1906.

party proceeded to the Wallsend and Walker ship-building works of Swan, Hunter & Wigham Richardson, Ltd., where they were received by Messrs. C. S. Swan and John Tweedy.

These works occupy 78 acres, with a river-frontage of 4,200 ft. There are 16 slips for building vessels (the greatest length being 900 ft.), and a yard for building large floating-docks. The engineering department includes modern machine-, fitting-, and erecting-shops, and also boiler-works. The dry-dock department contains two pontoon floating-docks to lift vessels up to 350 ft. in length, and a dry-dock, 550 ft. long and 76 ft. wide at the entrance.

A noticeable feature of the works is the immense glass-roofed sheds covering four of the berths. The largest of these sheds is 740 ft. long, with a clear inside width of 100 ft. and a height of 144 ft. All the building-sheds are equipped with numerous overhead electric cranes. Under one of the sheds is being built the "Mauretania," one of the two great mail-steamers ordered by the Cunard Company, under its contract with the British Government, and designed to be the fastest vessels in the Atlantic trade and by far the largest in the world. Each will be about 800 ft. long, with a beam of 88 ft., and of 32,000 gross registered tons. Steam-turbines will be used for propelling the vessels, and they are to be of sufficient power to drive the ships at an average service-speed of 25 knots an hour. The accompanying illustration shows the party with the big new Cunarder as a background.

After this visit, luncheon was served on the steamer, *en route* to the mouth of the Tyne, where the party was received by Mr. Ivan C. Barling, the resident engineer, and inspected under his guidance the works of Sir John Jackson, Ltd., now reconstructing a portion of the north pier.

The entrance to the Tyne is exposed to the stormy North Sea, and a shallow bar, flanked by ugly reefs and swept by heavy seas together with the unfavorable nature of the bottom, made the place, long ago, the dread of mariners. In 1854, the extensive north and south piers were begun, and subsequently carried a considerable distance seaward, thus forming a sheltered entrance to the river, and at the same time adding to the scour, so as to deepen the channel. The south pier has stood; but about 8 years ago a violent storm made a breach in the north pier, which was extended by subsequent storms until the opening was about 300 ft. wide. This injury is now to be repaired by a new structure, 1,500 ft. long, which, when finished, will make a straight breakwater, half a mile in length, replacing the former partly straight and partly curved one. The foundations will be carried down to hard shale, doing away with the rubble-works formerly employed at the bottom; and the whole structure will be of concrete-blocks, bonded together, the largest weighing from 30 to 40 tons.

The party, which was, throughout this excursion, under the charge of Mr. Joseph Fairless, returned to Newcastle during the afternoon.

2. *Hylton, Dorden and Hordon Collieries.* This party, conducted by Mr. F. R. Simpson, and conveyed by special train,

visited first the Hylton colliery of the Wearmouth Coal Co., Ltd., where they were received by Mr. M. W. Parrington, and afterwards entertained at luncheon by the company.

Hylton colliery, at the Wear steel-works, on the northern bank of the Wear, about 2 miles above Sunderland, has three brick-lined shafts, of which the east pit, 20 ft. in diameter, is hoisting from the Hutton seam, of an average thickness of 4.5 ft. of clean coal, at a depth of 1,580 ft.; the west pit, also 20 ft. in diameter, hoists from the Maudlin seam, 5.75 ft. thick, at a depth of 1,440 ft.; and the south pit, 15 ft. in diameter, sunk to the Hutton seam, is the ventilating or fan-shaft, both of the others being downcasts.

The winding-ropes, of mild steel and Lang lay, are built up of six strands of 17 wires each; they are 5.25 in. in circumference, weighing about 26 lb. per fathom. The ropes are capped in the ordinary way, with hooped sockets, and riveted.

The cages in the east pit are designed and built for the adoption of a counter-balance-rope. The arrangement is described in Mr. Parrington's paper on "The Adoption of a Balance-Rope at Hylton Colliery," *Transactions of the Institution of Mining Engineers*, vol. xxvi., p. 294 (1903).

At the east and west pits there are high-pressure winding-engines, having each two cylinders, 34 in. in diameter by 6 ft. stroke, with double-beat valves and automatic cut-off gear. Steam-pressure, 120 lb. per sq. in. Parallel winding-drums, 20 ft. in diameter on the oak cleading, 7 in. thick, fixed upon steel lagging plates, are fitted with strap-brakes, worked by a foot-lever, and with powerful steam-brakes.

The Waddle ventilating-fan, 25 ft. in diameter at the blade-tips, driven direct by a tandem compound engine, with cylinders 18 and 30 in. in diameter by 2-ft. stroke, is at present running at 50 rev. and circulates 200,000 cu. ft. of air per min., at 1 in. of water-gauge.

The whole of the surface and the shaft-bottoms are electrically lighted, the current being supplied from a Tyne dynamo driven by a Robey 50-h.p. engine, and giving, at 600 rev. per min., 400 amperes at 110 volts—equivalent to 700 lamps of 16 candle-power.

At the present time, the coal is hauled by compressed-air engines with cylinders 10 in. in diameter by 16 in. stroke, working on the main-and-tail system. When a permanent method of haulage is adopted, these engines will become secondary, and will be moved farther inbye.

At the neighboring Wearmouth colliery two shafts were sunk with great difficulty (the work occupying 10 years, from 1826 to 1835), through a considerable amount of quicksand near the surface, and heavy water (2,000 gal. per min.) in the magnesian limestone below, to cut the Hutton seam at the depth of 1,723 ft. They are 100 ft. apart; A, the upcast, being 11.5 ft. and B, the downcast, 12.5 ft. in diameter.

The principal coal-seams sunk through are as follows:

Name of Seam.	Thickness of Coal. Ft.	In.	Depth from Surface. Ft.
Five-Quarter,	2	10	1,077
Main,	2	11	1,509
Maudlin,	5	3	1,605
Low Main,	1	4	1,657
Hutton,	4	6	1,723

The Maudlin and Hutton seams are now being worked. The former has been worked under the sea for a distance of about 3,000 ft.

Leaving Hylton colliery, the special train proceeded to the Dawdon colliery, owned by the Marquess of Londonderry, where the party was received by Messrs. W. Corbett and E. S. Wood.

This colliery presents an interesting example of the Pitsch freezing-process in sinking through quicksand. In April, 1900, the Castlereagh and Theresa shafts, each to be 20 ft. in internal diameter and 1,800 ft. deep, to the Hutton seam, were begun. The following strata were traversed above the Coal-Measures: magnesian limestone, 356 ft. 10.5 in.; marl slates, 3 ft. 1 in.; yellow sands, 92 ft. 4 in.

Sinking was through the heavily watered ground by means of pumps capable of dealing with 7,000 gal. per min., until the Theresa shaft had reached 350 and the Castlereagh 204 ft., in magnesian limestone; when the water amounted to 7,050 gal. per min., or more than could be raised by the pumps. It was then decided to freeze the shafts, so as to sink through the remaining thickness of magnesian limestone, and 92.5 ft. of yellow sands, without additional pumping-plant.

Preparatory to freezing, 28 bore-holes (begun April, 1903, and completed April, 1904) were sunk around each shaft to a depth of 484 ft., being 21 ft. into the Coal-Measures. Freezing was then commenced, and continued until Feb. 16, 1906. During this period both shafts were sunk through the frozen limestone and sand into the Coal-Measures, and the whole of the water-bearing strata was lined with cast-iron tubbing.

The shafts are now being sunk through the Coal-Measures; the Castlereagh being 810 and the Theresa 780 ft. deep. The water in each amounts to only 100 gal., and is being hoisted by the sinking-engine. The Castlereagh has 456 ft. of cast-iron tubbing, and 108 ft. of brickwork below that. In the Theresa, the tubbing occupies 438 ft., and the brickwork 204 ft.

From Dawdon colliery, the special train proceeded to Horden colliery, where the party was received by Mr. J. J. Prest, and, at the close of the visit, entertained with afternoon tea and light refreshments, tendered by the Horden Collieries, Ltd.

The royalties leased and owned by this company cover about 19,000 acres. The Shotton and Horden collieries have been developed during the past six years to work a portion of this property, and it is intended to open two more collieries, at Hesleden and Castle Eden. The present production averages 2,500 tons of coal per day.

The three shafts at Horden were sunk about 1,050 ft. through the magnesian limestone to the Coal-Measures. The north and south (downcast) shafts are 20 ft., and the east (upcast) shaft is 17 ft. in finished diameter.

The north shaft is 1,260 ft. deep, and reaches the Hutton seam at 1,200 ft. It was begun in November, 1900, and completed in July, 1904. Water was encountered at 198 ft. From this point downwards, to 522 ft., the shaft has cast-iron tubbing, above and below which, it is secured with solid 14-in brickwork. The shaft passes through the Five-Quarter, Main, Low Main and Hutton coal-seams, all of workable section.

The south shaft has been sunk 907 ft. to the Main coal-seam, and will be used to work the Five-Quarter and Main seams. The east shaft, at present down to the Hutton seam, will soon be carried to the Harvey seam, about 120 ft. below.

At present, about 800 tons of coal per day are hoisted through the east pit, the permanent shaft-siding underground in the north and south pits not being completed.

For a period of three years during the sinking of these shafts, from 3,000 to nearly 10,000 gal. of water per min. had to be pumped from the magnesian limestone and the yellow sands before the Coal-Measures were reached.

3. *Bamburgh and Alnwick Castles.* This excursion was under the charge of Mr. W. Cochran Carr. A party was conveyed by special train to Lucker station, and thence in carriages about 5 miles to Bamburgh Castle, where they were hospitably entertained as the guests of the present owner, Lord Armstrong, at a luncheon, served in the magnificent banqueting-hall of the castle; after which they drove via Seahouses and Embleton to Alnwick Castle, the seat of the Duke of Northumberland, and were entertained at afternoon tea in the "Plough" hotel, near the Alnwick railway-station, subsequently returning by special train to Newcastle.

Bamburgh, or Bamborough Castle, situated upon the open shore of the North Sea, on a precipitous bluff, 150 ft. high, which constitutes the outcrop of a large dyke of igneous rock, is one of the most magnificent buildings of its kind in England. It is said to have been erected by King Idor of Northumberland, and to have suffered many sieges and assaults before it became, in the 18th century, the property of Lord Crewe, Bishop of Durham, who bequeathed it to trustees for sundry charitable purposes, including the maintenance of a home for children. In the course of time, many of these purposes became obsolete, and the revenues of the manor were found inadequate, while the situation of the castle proved inconvenient for the rest.

Fortunately, the deed of trust, as construed by the Lord Chancellor, provided a way out of the difficulty, and the Armstrongs, upon payment of a large sum to the trustees, acquired the property. Since that time, it has been restored at great expenditure, and is now a splendid and complete example of a mediæval palace-castle. It was specially pleasant to the guests of Lord Armstrong on this occasion, to know that the wealth available for this purpose was largely acquired by Sir William Armstrong, father of the present owner, as the reward of his inventions and improvements in the manufacture and manipulation of steel.

But Bamburgh has a still greater claim upon sympathetic interest. From its high bluff, the Farne islands, which are, indeed, simply precipitous continuations of the outcrop of the dike upon which the castle stands, can be clearly seen in the offing; and one of these islands was the scene of the ever-memorable heroism of Grace Darling, whose tomb (worthily built, like the tomb of a queen) is in the village churchyard. The event occurred almost a hundred years ago, and the story cannot be retold here, but the whole world remembers the thrill of admiration which it then experienced.

At Alnwick Castle, the party had only time to inspect the several stately courts and the grim dungeons.

On Wednesday evening, a Conversazione was held at the invitation of the North of England Institute of Mining and Mechanical Engineers, in the Laing art-gallery at Newcastle.

Thursday, August 2.

For this day, the following excursions were arranged:

1. *The Chesters and Borcovicus Camp.* This party, under the charge of Mr. J. P. Gibson, went by special train to Chollerford, and then by carriage (upon the invitation of Mrs. Clayton) to The Chesters. After luncheon at the George Inn, at Chollerford, the party drove, along the route of the old Roman wall, to Borcovicus camp, and thence to Haltwhistle, where afternoon tea was served in the Town Hall, after which the special train conveyed them back to Newcastle.

Apart from the delight of driving through the beautiful landscapes of this part of England, the interest of this excursion, which followed about 28 miles of the historic Roman wall, was due to the abundant antiquarian knowledge and the unwearied patience and enthusiasm of Mr. J. P. Gibson, under whose guidance the party could not fail to acquire a vivid realization of the local conditions attending the holding of this wall by the Roman legions during a critical period of the history, not only of Britain, but also of Rome. The latest book of Mr. Rudyard Kipling shows that he has studied this period in the light of the discoveries made at The Chesters and at Borcovicus.

2. *The Elswick Works of Sir W. G. Armstrong, Whitworth & Co., Ltd.* This party, in charge of Mr. Norman Redmayne, went by special electric tram-car to the offices of the Ordnance Department of these works, where they were received by Capt. Lloyd.

At this important and famous establishment, the visitors were able to see, in the bridge-yard, several large hydraulic cranes and dock-gates under construction; and in the fitting- and erecting-shops, hydraulic engines for handling guns, deck pumping-plants and smaller machines for generating hydraulic power on board ship, etc.

In the Ordnance Department, the first shop is devoted to turning barrels for the 12-in. and 9.2-in. guns, etc. Some of the latest pattern 50-caliber guns are under construction for the Government. These tubes, in some cases 40 and 50 ft. long, must be finished correctly to within 0.001 in. This work is very delicate, and requires long experience and high skill. There are also a number of machines for accurately "rifling" the guns. The cradles, to carry the guns, so as to secure their greatest efficiency and to take up the shock of the recoil, are also made here. The trunnions are formed on the cradle, not on the gun, and are so

arranged that, when the gun is at rest, they can turn round a small fulcrum resting on a spring. When, however, the gun recoils, the spring gives way, and a sufficiently large bearing-surface comes into play. By means of this device, a gun weighing 28 tons can with ease be raised and lowered by hand. The recoil is taken up by a piston working in a hydraulic cylinder. A great saving in weight is the result.

Several Elswick submerged torpedo-tubes were shown in a state nearing completion, and a very fair idea could be obtained of their working.

In another large gun-shop, a large rifling-machine was seen at work on a 12-in. gun. Farther on, under the same roof, the largest naval gun-mountings are erected. These consist of an armored gun-house, an engine-room beneath, and an ammunition-passage, which extends to the bottom of the ship. To permit their completion in the shops, wells 40 ft. deep have been dug in the floor. The mountings now in hand will carry two 12-in. guns, are worked by hydraulic machinery, and weigh 420 tons.

A 6-in. disappearing mounting, built at the Armstrong works in Pozzuoli, Italy, was seen ready for use, and many milling-machines, used in the manufacture of breech-mechanisms, were also shown in operation.

At 6.15 p.m., the special train left Newcastle for Glasgow, where it arrived at 10.10 p.m.

Friday, August 3.

The Glasgow headquarters were at the Windsor Hotel, and the arrangements for entertainments and excursions had been made by a Committee of the West of Scotland Iron and Steel Institute and the Mining Institute of Scotland, of which Mr. A. Campion was Secretary.

Friday was occupied in a memorable excursion, embracing the whole party, on the firth and lochs of the Clyde. The party went by special train from Glasgow to Gourock, where the beautiful swift steamer "Duchess of Hamilton" was boarded for the day's voyage. Luncheon and afternoon tea were served on the steamer; and the band of the 1st Lanarkshire Royal Engineers (Volunteers) played many pieces of inspiriting music, mostly connected with America, and beginning with Sousa's "Stars and Stripes."

The bewildering maze of land-locked sounds and channels, bordered by picturesque hills, which lies between the mouth of the Clyde and the open sea, is a continuation of the highlands into the ocean. Indeed, the salt-water "lochs" are more numerous and not less lovely than their fresh-water sisters in the Trossachs. In Loch Long, the steamer was separated by a single heathery ridge only from Loch Lomond, beyond which, and behind Ben Lomond, lies Loch Katrine. This voyage was simply trailing through the Highlands by steamer instead of land-conveyance. Beautiful illustrated guide-books and special maps, distributed

to the guests, added to their intelligent enjoyment of the scenery by calling their attention to its innumerable romantic features and historic and literary associations. The accompanying illustration, engraved from a photograph taken on the steamer, will constitute for those who were present a precious souvenir of this unique day's delight.

On Friday evening, a reception was given in the City Chambers by the Lord Provost and Corporation of Glasgow, beginning at 7.30 p.m. The time was occupied in social intercourse and wandering through the salons and corridors of the magnificent City Chambers until 8.50, when the guests assembled in the banqueting-hall, where brief addresses were made by the Lord Provost, William Bilsland, and Presidents Andrew Lamberton of the West of Scotland Iron and Steel Institute, Robert W. Hunt of the American Institute of Mining Engineers, and R. T. Moore of the Mining Institute of Scotland. Refreshments were served continuously from buffets on two floors of the building; and varied and attractive musical programmes were given by Herrn Iff's famous orchestra in the banqueting-hall until 8.50, and in the council-hall until 10.30; by the Glasgow Corporation Band in the upper corridor throughout the evening; and by the Glasgow Select Choir in the banqueting-hall, from 9.20 to 10.45. The last-named was a thrilling and charming vocal concert, comprising a variety of humorous, patriotic and national songs, presented by excellent soloists and a large and well-trained chorus, the performance of which reflected much credit upon Mr. Learmont Drysdale, the conductor. Altogether, this reception was generally regarded as one of the most impressive and delightful of the social entertainments enjoyed in Great Britain.

Saturday, August 4.

At 9.30 a.m., the party left Glasgow by special train for Edinburgh, where they arrived at 11.25. In the afternoon, they were conveyed by special train to the ancient city of Dunfermline, 16 miles from Edinburgh, being received by Dr. John Ross, Chairman of the Carnegie Dunfermline Trustees, and conveyed in carriages to the Baths and Gymnasium, the historically famous Abbey, and the Glen. Luncheon, served in a marquee erected for the purpose in Pittencrieff Park, was enlivened by music from the Band of the Carnegie Trust and the Pipers' Corps of the 6th V.B.R.H. (Black Watch) regiment.

The guests were then conveyed in carriages 6 miles to North Queensferry, where the celebrated Forth bridge is situated. Taking a steamer here, they sailed under the bridge to South Queensferry, where coaches received them for the homeward drive to Edinburgh, through the extensive and lovely Dalmeny Park, thrown open for this occasion by the courtesy of the owner, Lord Rosebery.

The excursion to Dunfermline, the birthplace of Andrew Carnegie, for many years a member, and lately, by unanimous election, an Honorary Member, of this Institute, was arranged at the special request of Mr. Carnegie, who was unfortunately prevented by the illness of his only daughter from adding to the enjoyment of the occasion by his personal presence. It would be hard to decide whether the ancient or the modern associations of Dunfermline are the more interesting; and it is quite impossible in this brief notice to do justice to either.

Dunfermline was in the 11th century the capital of Scotland, under King Malcolm Canmore, whose queen, Margaret of Hungary, has long been a saint of the Catholic Church, and scarcely less revered by Protestant Christians. The remains of her shrine are carefully preserved in the Abbey, which contains also the remains of "good King Robert, the Bruce." Many sovereigns are buried here. The late Dean Stanley said that in Dunfermline Abbey reposes more royal dust than in any other locality in the United Kingdom. And other sovereigns have been born here—among them, Charles II., "the Dunfermline boy who lost his head."

Industrially, Dunfermline has been for two centuries the center of the damask linen manufacture, which now employs, under conditions of comfort and prosperity of which the town is justly proud, some 6,000 operatives. The town owns, moreover, a valuable coal-field in the rich mineral district of West Fife, the royalties from which have enabled it, while keeping taxation at a very low rate, to provide for its citizens many sanitary and æsthetic advantages not usually within the reach of small communities.

But to all these blessings has been added in recent years the magnificent gift of $2,500,000 by Mr. Carnegie, the income of which is wisely administered by a body of trustees in such a way as to benefit, without pauperizing, the recipients of the benefaction. The operations of the Carnegie Dunfermline Trust comprise a fine library, a technical college, public baths and gymnasium, and the priceless Pittencrieff Park and Glen, which are maintained by an endowment yielding $125,000 per annum. The trustees are constantly engaged upon new educational experiments: a school of hygiene; a school of music; a school of weaving, etc., etc.

The present result is a model town, inhabited by industrious, prosperous and self-respecting people. It is said that scarcely a family in it has not a member in America. Certainly the display of American flags, and the "whirlwind" reception of waving handkerchiefs and hearty cheers, which greeted our cavalcade as it passed through the streets of Dunfermline, formed a fitting climax to the cordial reception we had encountered in the United Kingdom. And as we drove by the house in which Andrew Carnegie was born, we could not but share the pride of the town in the man who was our fellow-citizen as well as theirs.

It would be, of course, improper to insert in this report arguments on contro-

verted sociological questions; but it may be permissible to suggest that the current theorizing about the "unequal distribution of wealth" usually concerns itself with the primary, and not the secondary, distribution; that the more important question is, what the first recipient of wealth does with it; that an absolutely equal primary distribution (if such a thing be possible) would never in the world make a Dunfermline; and that, conceivably, the social system which incidentally produces Dunfermline may be not altogether worthy of condemnation.

On Saturday evening, a final banquet was given by the Edinburgh Reception Committee, in the Hall of the Edinburgh Merchant Company. Deputy Lord Lieutenant John Cowan occupied the chair, and offered toasts to the King, the President of the United States, and the American guests (responded to by President R. W. Hunt). Mr. Charles Kirchhoff, past-President A.I.M.E., proposed a toast to the City of Edinburgh (acknowledged by the Lord Provost of Edinburgh); the health of Secretary Brough of the Iron and Steel Institute and Mr. Sidney, his assistant, was proposed by Mr. Edgar C. Leonard, and acknowledged by the two gentlemen named; the toast, to "The Interests of Secondary and Commercial Education," was offered by Secretary Bennett H. Brough, I. & S.I.; and the final toast, "The Chairman," by Secretary R. W. Raymond, A.I.M.E., who included in his remarks a recognition of the services of the Edinburgh Reception Committee (especially those of Mr. Cowan, its leading spirit), and a hearty farewell to the many personal friends made by the members of the party during their brief stay in Scotland. A brief but cordial reply from Mr. Cowan concluded the proceedings.

The Edinburgh Merchant Company is one of the old associations (chartered by Charles II.) which has long ceased to be active in the commercial departments which it was formed to control. It now retains its magnificent hall, and a large income which it devotes to educational purposes.

The proceedings of this banquet were interspersed with music of a peculiarly thrilling character, consisting of Scottish airs, played by Mr. Windermere, violinist, and Scottish ballads, sung by Mr. Furness, baritone—both supported by a judiciously subdued piano accompaniment. Even those who had often experienced, and who thought they understood, the charm of this national music, gained a new conception of it from this never-to-be-forgotten interpretation.

Taken as a whole, this banquet was pronounced by all who took part in it a worthy conclusion of the Wonderful Week of the Northern Trip.

III. The Visit to Wales.

Cardiff Reception Committee.—Sir William Thomas Lewis, Bart. (*Chairman*); T. Hurry Riches and David E. Roberts (*Honorary Secretaries*); The Lord Mayor of Cardiff, Alderman Robert Hughes; The Deputy Lord Mayor of Car-

diff, Alderman W. L. Yorath; The Marquess of Bute; The Earl of Plymouth; The Lord Viscount Tredegar; and many other eminent citizens.

***Ladies' Committee.*—The Lady Mayoress, Mrs. Robert Hughes; The Deputy Lady Mayoress, Mrs. W. L. Yorath; The Marchioness of Bute; The Countess of Plymouth; and other ladies of social eminence.**

About twenty members of the American Institute party availed themselves of the kind invitation extended by the Institution of Mechanical Engineers to attend the Cardiff meeting of that Society. The first session was held Tuesday, July 31, at 10 a.m. in the Hall of the South Wales Institute of Engineers, Park Place, President Edward P. Martin presiding. The Right Hon. the Lord Mayor of Cardiff, Alderman Robert Hughes, and members of the Local Reception Committee, and the President and Vice-President of the Council of South Wales and Monmouthshire University College, welcomed the President, Edward P. Martin, Esq., the Council and Members of the Institution and the American guests.

Following the address of welcome, papers were read and discussed. At 1 p.m., a delightful luncheon was served in Park Hall by invitation of Messrs. Guest, Keen & Nettlefolds, and, in the afternoon, the Bute docks of this company and the Dowlais-Cardiff iron- and steel-works were visited. The ladies enjoyed a separate excursion to St. Fagin's Castle, where afternoon tea was attended through the courtesy of the Right Hon. the Countess of Plymouth.

The evening was devoted to a reception and dance at the Park Hall, given by the Right Hon. the Lord Mayor of Cardiff, Alderman Robert Hughes, and the Lady Mayoress.

The second session was held at the Hall of the South Wales Institute of Engineers, Wednesday, Aug. 1, at 10 a.m., President Martin presiding. Papers were read and discussed. After the session, a visit was made to Penarth docks by special train, kindly furnished by the Taff Vale Railway Company, which also provided luncheon. The ladies had the choice of two trips in the afternoon: (1) Afternoon tea in the grounds of Caerphilly Castle; and (2) Drive to Castell-Coch and afternoon tea given by Mrs. Henry Lewis.

Thursday, Aug. 2, was spent in alternative visits to the Barry docks, to the Powell Duffryn Steam Coal Company's Bargoed colliery, and to the Newport transportation bridge

and the Alexandria docks at Newport. From 3 to 6 p.m., the time was most pleasantly occupied with a garden party given at Cardiff Castle by the Marchioness of Bute.

In the evening a Welsh concert, followed by dancing, was given at Park Hall by the Local Reception Committee. The programme included music by the band of the Grenadier Guards, the Rhymney Male Voice Choir of eighty singers, and other characteristic Welsh music.

Friday, Aug. 3, was occupied by alternative excursions to Chepstow Castle and Tintern Abbey, and to Ilfracombe by steamer. The evening was devoted to an illuminated *fête* in the Sophia Gardens, Cardiff. Invitations were also extended to visit manufacturing works in Cardiff and vicinity, at any time during the meeting.

IV. The Excursion to Germany.

Düsseldorf Reception Committee.

Fr. Springorum (*Chairman*), Dr. C. Schroedter (*Secretary*), Dr. W. Beumer, Moritz Böker, Dr. W. Borchers, W. Brügmann, H. A. Bueck, Franz Rich. Eichhoff, Dr. Fahrenhorst, Gisbert Gillhausen, Walter J. Hilger, Heinrich Kamp, Fr. Kintzlé, Ottokar von Kraewell, H. Lueg, Wilhelm Marx, Paul Reusch, Hugo Sack, E. Schaltenbrand, Aug. Thyssen, Dr. Wüst.

Ladies' Committee.

Frau Dr. Beumer, Fräulein Beumer, Fräulein Carola Dürr, Frau F. R. Eichhoff, Fräulein Hilger, Frau Ernst Lueg, Frau Hugo Sack, Frau Schaltenbrand, Frau Dr. Schroedter, Fräulein Elsbeth Spannagel, Fräulein Taussig.

The following extract from an unofficial preliminary sketch, published in *Bi-Monthly Bulletin*, No. 11, September, 1906, is here officially repeated, because it cannot be improved by its author as an introductory summary:

The interval between August 4 and August 13 was spent by individual members and their friends as pleasure or business suggested. Some accepted the hospitality of new or old friends in England; some "motored" through England; some coached in the Trossachs; some skipped over to Holland, and approached Germany by peaceful canal-routes; some went to Windermere and some back to London for certain sights overlooked in the first mad week. But a goodly number—something over 100—(many more than had been at one time hoped for) turned up at the rendezvous in Düsseldorf.

This supplementary visit, planned by the Society of German Ironmasters, and carried through with unqualified and brilliant success by Dr. Schroedter, the executive officer of that body, was just what was needed to crown the experiences of our memorable month. It was a series of charming, varied, interesting and

instructive reunions and excursions, exhibiting in equal measure the lovely scenery, the industrial progress and the warm hospitality of Germany. No part of the world more readily lends itself to such a proceeding than the region of the Rhine; no people know better "how to do it" than the people of that region; and we saw both land and land's folk at their very best, in those five golden days in and about beautiful Düsseldorf, along the storied, vine-clad Rhine, and through the famous Bergenland!

The guests, arriving at Düsseldorf on Monday, August 13, were accommodated in the Park Hotel (where the Local Committee had established its headquarters) and in other first-class hotels of the beautiful city of Düsseldorf. An informal gathering in the evening, at the Park Hotel, effected a wonderfully quick and mutual relation between visitors and hosts, and inaugurated many acquaintances which ripened speedily into friendships—for which result the main credit should be given to the Ladies' Committee, the members of which charmed not only the gentlemen, but also the ladies of the party. The former of these feats would have been easy, not to say inevitable; but the accomplishment of both is worthy of much higher praise!

Tuesday, August 14.

This day was devoted to an excursion on the chartered steamer "Rheingold" to Walsum, exhibiting the harbor and shipping-facilities of the lower Rhine. The "Rheingold" was festively arrayed; and the response, through the display of American flags, from the great industrial establishments along the river was surprising to us Americans, who were forced to confess that in our country, whatever might be our friendly feeling towards German visitors, we would not be likely to have on hand, for its expression, such a supply of their national banner.

The steamer passed under the beautiful, though incomplete, Rhine bridge at Homberg, and turned at Walsum (luncheon having been meanwhile served on board) in order to stop at Rheinhausen, where the new Friedrich Alfred works of the Krupp Co. were visited by the gentlemen of the party, while the ladies were entertained by a visit to the workmen's village near the works, and a collation, served in the boarding-house of the village. The gentlemen's party was likewise entertained, in a large hall (part of the new works), picturesquely decorated

with German and American flags, evergreens, etc.; and addresses were made by Director Klönne for the company, President Hunt and past-President Kirchhoff for the American Institute of Mining Engineers, and Secretary Schroedter of the German Society of Ironmasters. The reunited party then returned to the steamer, which conveyed them back to Düsseldorf.

It would be impracticable to give here a complete account of the immense industry controlled by the late Friedrich Alfred Krupp, which passed at his death in November, 1902, first into the possession of his eldest daughter, Bertha, and subsequently, in accordance with his wishes, was incorporated as a joint-stock company, with a capital of 160,000,000 marks (a little less than $40,000,000), of which she continues to hold practically all the stock. Friedrich Krupp, the founder of the firm, was born in 1787 and died in 1826. His son, Alfred Krupp, was born in 1812 and died in 1887; and his grandson, Friedrich Alfred Krupp, was born in 1854 and died in 1902. During these three generations was developed the world-famous business which now owns:

Cast-steel works at Essen-Ruhr with proving-grounds at Meppen and Tangerhütte; three collieries, at Essen, Hordel, and Hordel-Eickel (near Bochum); a great number of iron-mines in Germany (10 of which have deep-workings, with complete machinery) and a share in sundry iron-mines at Bilbao, Spain; four iron-works (the Friedrich Alfred, near Rheinhausen; the Mülhofener blast-furnace plant, near Engers; the Hermanns blast-furnace plant, near Neuwied; and the Sayner foundry and engineering works, at Sayn); a shipping office for sea-going steamers at Rotterdam; the Annen steel-works, in Westphalia; the Grusonwerk, at Buckau, near Magdeburg, and the Germaniawerft, at Kiel.

These establishments employ about 122,000 workmen and 3,000 officials. The total number (including wives and children) was, according to a census taken in 1905, about 183,000 persons.

The Friedrich Alfred works, visited on this occasion, are on the left bank of the Rhine, opposite Duisberg-Hochfeld, and comprise at present six blast-furnaces, an open-hearth steel-plant, a rolling-plant, etc. Particulars of all these departments were freely given to the visitors, in an illustrated volume prepared for the purpose. The admirable up-to-date equipment and management of the works commanded universal admiration; but perhaps the most impressive feature was the array of gas-engines, driven by blast-furnace gas—an improvement not yet as well known and highly valued in America as it is certain soon to be.

"Margaretenhof," the workmen's village connected with these works, is only one of the many colonies and dwellings owned by the company, in which more than 30,000 persons live, besides those who lodge in the boarding-houses. This village is beautifully laid out and constructed, so as to avoid straight streets and barrack-like blocks, and give to each dwelling its own picturesque individuality. It is reported that the company owns, in a dozen or more such "colonies," about 6,000 dwellings, besides model lodgings for unmarried workmen. Use of the accommodations thus provided by the company is not at all compulsory. On the contrary, so far as could be ascertained, it is a prize to be desired and sought.

On Tuesday evening, a reception was given by the City of Düsseldorf in the Kaisersaal of the stately and commodious

Tonhalle. The hall was festively adorned, a noble background being presented by the great picture of the Niederwald Denkmal, at the back of the stage. Music of a high order was furnished by the famous Düsseldorf Mannerchor, founded in 1904, under Director M. Neumann. Oberburgermeister (Mayor) Wilhelm Marx, in an eloquent German speech, which was repeated in English by Director E. Schaltenbrand, emphasized the friendly relations between American and German engineers and ironmasters, and extended to the guests on this occasion the welcome and hospitality of Düsseldorf. President Hunt, A.I.M.E., replied in English, subsequently translated into German by Secretary Raymond. A buffet and numerous small tables at the sides and rear of the great auditorium provided a collation, with abundant opportunity for social intercourse, which was agreeably prolonged to a late hour.

Wednesday, August 15.

The ladies were conducted by the Ladies' Committee to view the parks, statues, art-galleries, etc., of the city; and the gentlemen were divided among three alternative excursions, visiting, respectively, by invitation of the proprietors, the following works:

1. *The Rheinpreussen Colliery* at Homberg-on-Rhine. After inspecting the works at Pit No. IV., the party was entertained at luncheon by Director Seidenberg, who made an address of welcome which was enthusiastically received.

This colliery belongs to the Haniel family, by whom it has been developed, in spite of great difficulties, to a model mining operation of the first rank, employing 8,000 workmen, and hoisting, from a depth of from 200 to 300 m., 8,000 tons of coal daily. There are 100 Coppée coke-ovens, 90 modern by-product ovens, and 118 more of the latter class under construction. The present daily product of coke is 710 metric tons, which the new ovens will increase to 1,350 tons. The dwellings, accommodating 2,550 families; the co-operative purchasing, benefit, and burial associations; and other arrangements for the advantage of employees, are admirable.

2. *The Phœnix Works*, Laar, and the *Rheinische Stahlwerke*, Meiderich, both near Ruhrort. The party visiting these works was entertained at luncheon, upon the joint invitation of both companies, in the "Erholung" (refreshment) restaurant, where appropriate welcome was expressed and acknowledged.

The Phœnix works are well known as models of modern arrangement and construction, especially as to the handling of materials and products. The quay receives on the South the tracks of the State railway ; on the West, it extends to the Rhine, which is connected with the works by a narrow-gauge road, serving also as a freight-line to the harbor of Ruhrort. A tunnel, 3,500 m. long, is destined to accommodate an electric railroad between the collieries and the steel-works of the company.

The blast-furnaces, basic-steel plant, rolling-mill and hydraulic presses of these works exhibit many interesting features of modern practice.

The Rhenish steel-works are likewise noteworthy for their arrangements for the unloading and transportation of materials. The iron-ore is received by water at Ruhrort, where it is transferred by two large conveyors and four steam-cranes to the railway-cars of the company. Among the various departments of the works, the plant for Martin and Thomas open-hearth steel, the hammer-plant, and especially the four engines driven by blast-furnace gas, were most interesting and suggestive to the American visitors.

3. *Gutehoffnungshütte*, at Oberhausen and Sterkrade. This party inspected the steel-works and rolling-mills at Oberhausen, and the shops for the building of machinery at Sterkrade, owned by the Gutehoffnungshütte Aktienverein für Bergbau und Hüttenbetrieb (mining and metallurgical company), and was entertained at luncheon in the Casino at Sterkrade, where Councilor Scheidtweiler, as the representative of the company, expressed a cordial welcome, which was acknowledged by past-President Charles Kirchhoff and Mr. E. S. Hutchinson, A.I.M.E.

From a beautifully printed, illustrated and bound hand-book presented to the guests, the following scanty particulars are taken : This company employs 22,000 workmen and 100,000 h.p. of motive energy; and produces annually 3,500,000 tons of coal, and 500,000 tons of pig-iron (making 450,000 tons of steel). Its iron-mines in Nassau, Siegerland, Bavaria, Lorraine, Luxemburg, and Belgium produce annually 400,000 tons of ore ; its limestone and dolomite quarries, 130,000 tons. Its six collieries have washing-plants handling 6,000 tons of coal daily. The company designs, manufactures and constructs almost everything in the line of steel, from small articles to the largest plants or structures. In the latter class may be named the steel floating-docks at Danzig, Wilhelmshafen and Kiel ; the roofed ship-building slips at Kiel ; the structural steel-work for giant cranes (up to 150 tons capacity) at Bremerhaven, Kiel, Vegesark, Hoboken, Dalmuir, and Tsing-tau ; floating-cranes at Ruhrort, Bremen, Kiel, Wilhelmshafen, and Rio de Janeiro ; bridges on the Rhine at Bonn, Düsseldorf, and Duisburg-Hochfeld, and many bridges in Germany and other countries, including 140 swing-bridges for the St. Gotthard railway ; railway-stations at numerous places ; complete mine-plants, pit-head frames, pumping-rods, etc.

On Wednesday evening, a festival banquet was given in the Tonhalle by the Reception Committee. Between 200 and 300

guests (including ladies) were present. The chair was occupied by Fr. Springorum, President of the Verein deutscher Eisenhüttenleute (Society of German Ironmasters) and Director-General of the Hoesch iron- and steel-works at Dortmund. The artistic *menu* displayed a bridge in progress of completion between Germany and America; and the spirit of the evening was such as might well have justified a picture of this bridge as completed. The great "Rittersaal" was decorated with German and American flags, etc., and excellent music accompanied the banquet, at the close of which the trumpet-corps of the 5th Uhlan regiment electrified the company with a magnificent fanfare.

The speaking began with an eloquent German address by President Springorum, in which he emphasized the leadership of engineers in the modern practice of international conferences; referred to the visit to Germany of American Mechanical and Mining Engineers in 1889; the visit to America, at the invitation of the American Institute of Mining Engineers, in 1890, of many of their German professional colleagues; and the presence, at the Düsseldorf Exposition of 1902, of John Fritz, the Nestor of American metallurgical engineers, with many others of that profession. In this connection, he alluded with feeling to the death of such members of one or both of the two societies as Holley, Jones, Hewitt, Thielen, Lueg Daelen, and Blass. After a condensed review of the progress of the iron-industry since 1890, and an interesting statement of the relative position and problem of Germany, Mr. Springorum concluded with a hearty greeting to the American guests. His address, repeated in English by Director Schaltenbrand, was received with much applause.

Dr. E. Schroedter, Secretary of the Society of German Ironmasters, called upon Privy Councilor Hermann Wedding, an honorary member of both societies; and Councilor Wedding responded in a brief and happy speech, defining the relation between theory and practice in the application of science to industry.

Upon the suggestion of Dr. Schroedter, the following cable-dispatch was unanimously adopted by the company, to be signed by the officers of the two societies and sent to John Fritz, Bethlehem, Pa., U. S. A.:

"**Two hundred members of the American Institute of Mining Engineers and the Society of German Ironmasters, gathered as friends, send to the pioneer record-maker in the rolling of steel and Nestor of the American steel-industry their hearty greeting and a joyful *Glück Auf!***"

There were no formal toasts; each speaker called up the next; and thus Dr. Wedding invited President R. W. Hunt, A.I.M.E., who spoke in English, and passed the word to Secretary Raymond, who spoke in German. Both addresses seemed to be so well understood by the company as to warrant Capt. Hunt's theory, that at a certain stage in the progress of friendship it made no difference in what tongue a man spoke; he would be sure to be understood! Upon that theory, the said speeches need not be here repeated!

The final sentiment, to the ladies, was offered by Dr. Beumer in a German speech, accompanied by a whimsical interpolated mis-translation by past-President Charles Kirchhoff, A.I.M.E., which elicited shouts of laughter. It is impossible to reproduce this unique *jeu d'esprit à deux*, which was a feat of acting, as well as of mutual ingenuity and wit. The undisturbed solemnity with which both parties played their game of cross-purposes warranted the suspicion that it was a "put-up game." But it was high art, and great fun, all the same!

After the formal conclusion of the banquet, conversation and dancing continued until a late hour.

Thursday, August 16.

This day was devoted to a general excursion into "das Bergische Land" (the mountain-district), a region of great industrial importance, as well as scenic beauty. The party went by special train to Vohwinkel, thence by mono-rail suspended electrically-driven train through Elberfeld to Barmen; thence by geared electric cars to Tölleturm; and thence by electric interurban line to Remscheid, where the gentlemen visited the steel-plant of Mr. Lindenberg, to witness the production of steel in electric furnaces, while the ladies were conveyed to Thalsperre, where dinner was served to the re-united party, which afterwards returned to Remscheid, and by train to Düsseldorf via Solingen. Between Remscheid and Solingen, the train crossed the Wupper valley on the famous Kaiser Wilhelm

bridge, a graceful steel structure, 350 ft. high above river-level, and 1,650 ft. long, with a main span of 525 ft.

At the Thalsperre, the party was entertained at dinner in the picturesque restaurant, commanding on all sides a charming prospect of hill and dale. Councilor Moritz Böker, who occupied the chair, welcomed the guests of the occasion in a humorous and eloquent speech, in which, alluding to the ancient and world-wide commerce of Remscheid, he quoted the legend that when Christopher Columbus first touched the soil of the New World, he met a Remscheid drummer, who wanted to know in what line, and for what concern, he was traveling! The limited time permitted no extended speeches; but a programme of excellent vocal music was presented as an accompaniment to the feast, by a chorus of 50 workmen from the various steel-works of the district.

The Langen Mono-Rail Suspended Railway, from Elberfeld to Barmen, (8.25 miles) is the only one of its kind now in operation. It carries annually more than 10,000,000 passengers, of whom about 3,000 daily are workmen, conveyed before 7 a.m., at the special rate of 5 pfennigs (about 1.2 cents), the return-fare, however (at any time of day), being thrice this sum. The maximum actual speed of trains is said to be 31 miles per hour. The cars are propelled by electric power. The experience of the party in traveling upon this railway contradicted emphatically the notion which seems to be so generally entertained, and so hard to dispel, that a vehicle suspended from a single rail is less secure in equilibrium than one supported on two rails below it.

The small Wupper valley contains a crowded population of 300,000 people; all surface rights of way have been long pre-empted; and, moreover, the mountain stream itself is subject to occasional heavy floods, and its bed affords no sufficient stability for the foundations of an ordinary elevated railroad. These conditions suggested the mono-rail double line of the Langen type now in successful operation.

The trip from Barmen to Tölleturm, by the cog-wheel electric *Bergbahn* (mountain railway) was full of picturesque beauty, commanding a succession of wide prospects over the hills, valleys and ravines which gave to this region its ancient name of "the mountain-land." At Tölleturm, a beautiful forest-retreat, the ladies stopped for luncheon, while the gentlemen proceeded to Remscheid. Remscheid is famous as the center of the German manufacture of hardware and cutlery—Solingen, celebrated formerly for its swords as it now is for razors, being included in the district. But the region is not less widely known for its varied and extensive manufacture of silk and other braids and trimmings, which are shipped all over the world. These industries, however, were not inspected by the party, which had only time to visit the steel-plant of Mr. Richard Lindenberg, where the Heroult electric steel-furnace was in operation. The presence of Dr. Heroult, the inventor, who had never before seen this plant, added interest to the occasion. The following excellent summary of the process and practice is taken from the New York *Iron Age* of Aug. 30, 1906:

"The methods were explained by Dr. Fr. R. Eichhoff, consulting metallurgist, who has just accepted a call to the Berlin University, and by Mr. Lindenberg, the manager of the works. It was frankly stated, however, that some of the details of the practice developed at the Remscheid works were withheld.

"The plant consists of a 2-ton Wellman open-hearth furnace, in which the raw material, principally scrap, is melted down, and the process is so conducted that the steel is over oxidized. The steel is then transferred to the Heroult electric furnace, where the operation is really that which is known in crucible-steel practice as 'killing' the steel. The quantity charged is about 2 tons, and the steel is purified in the electric furnace by the addition of scale or ore, and thus the elements in the metal, like silicon, carbon, manganese and phosphorus, are oxidized, sulphur, however, being an exception. The slag is cast off by tilting the furnace. Then a neutral slag is formed in the furnace by additions of lime and sand, under which deoxidation is carried on by means of carbon.

"Manganese, tungsten or other additions to the steel may be made to it by adding to the covering slag oxides of manganese or tungstic acid, and it is a special advantage of the method that practically all of the manganese thus added is recovered in the steel. The fact that the slag is white shows that no iron or other oxides are left in it. The yield therefore is high, being on an average 92.5 per cent. in the form of hammered blooms. The phosphorus contents of the steel have averaged 0.005 and of sulphur 0.012 per cent. The charge requires from 2 to 2.5 hr. independent of the size of the furnace.

"At Remscheid, experience has shown that with a 2-ton furnace the cost of the steel can be brought down to 120 marks, and it is estimated that with a 10-ton furnace it can be brought down to 90 marks per ton. With a 2-ton furnace the requirement of electric power is 360 kw. per ton of steel, and it is estimated that with a 10-ton furnace this will be reduced to 150 kw. At Govtfors, Sweden, a 5-ton electric furnace has been in successful operation for a considerable period. During the visit of the engineers a cast of steel was made which poured quietly, while the stock of hammered blooms shown at the works and samples of bars proved it to be of high quality."

The visitors were subsequently entertained at luncheon by Mr. Lindenberg, the proprietor of the works, and then conveyed by electric tram-cars to the Thalsperre, where they rejoined the rest of the excursion-party for dinner. The Thalsperre (Valley-lock) is one of the largest and most beautiful of a number of similar dams and reservoirs, constructed to store and control the rainfall of this region. The masonry dam, crossing the valley of the Eschbach, is 160 m. long, 26 m. high (including foundation and upper breast-work of 1 m.), 15 m. thick at the bottom, and 4 at the top. The reservoir holds 1,100,000 cu. m.; and the æsthetic feeling of the Germans has utilized it as a lovely lake, surrounded by a park, in which is situated the restaurant where dinner was served to the excursionists.

Friday, August 17.

This last day of the official programme brought the crowning enjoyment in a trip up the Rhine, which was favored by the loveliest of early autumn weather—real Rhine weather! The party was conveyed by special train to Coblenz, from which point a telegram was dispatched to the workmen's chorus of Remscheid, of which the following is a translation:

"In joyful remembrance of yesterday's admirable and heart-stirring lyrics, the American Institute of Mining Engineers and the Society of German Ironmasters extend to the Mannerchor of the steel-works of Remscheid and vicinity their cordial thanks, with the hope that German song and German labor may always continue to be the treasured jewels of the Bergische Land!" (Signed) Hunt, Springorum, Raymond, Schroedter, Beumer."

The extensive wine-cellars of Messrs. Deinhard & Co. at Coblenz were inspected with much interest, which culminated in an elaborate luncheon, at which famous vintages of the Rhine were served, while the "Rheinland" chorus, composed of employees of the firm, rendered excellent vocal music. Mr. Karl Wegeler, a member of the present firm, welcomed the guests in a graceful and humorous English speech, to which President Hunt, A.I.M.E., replied; and Dr. Schroedter proposed the health of Privy Councilor Julius Wegeler, a retired member of the firm, who was present as a guest, despite his advanced age. This sentiment was received with much enthusiasm.

The party, preceded by a band composed of iron-workers from the Saar district, then marched in procession through the streets of Coblenz to the pier on the Rhine, where a gaily decorated steamer, the "Ernst Ludwig, Grossherzog von Hessen," awaited them, and subsequently conveyed them up the Rhine as far as Boppard, and back to Düsseldorf. The festive proceedings on board the steamer defy the reporter's art. There was a merry dinner on deck, with more or less eloquent and more or less audible speech-making; there was a graceful and fascinating minuet (peremptorily encored), performed, in appropriate old-fashioned costume, by Mrs. Schroedter and Misses Spannagel, Dürr and Wedding; there was a general "polonaise" of merry and unceremonial character; there was much good music, furnished by the band of the Röchling works, of Völklingen; there was more fun and sentiment than any historian would dare attempt to record; and, finally, there was an improvised song, half-English and half-German, from the versatile Dr. Beumer, the chorus of which, to the old student-tune of "Hu-pei-dee, hu-pei-da!" was vociferously sung by the party. Two lines of this memorable lyric will indicate its nature:

"We dream, in the sleeping-car,
"Noch davon, wie schön es war!"

This concluded the formal programme of excursions from Düsseldorf as a center; but two supplementary trips remain to be noted.

The Visit to Luxemburg.

A small party, under the guidance of Engineer Otto Petersen, went on Saturday to Luxemburg, where they were royally entertained at a banquet in the evening, and visited on Monday the magnificent Differdingen works of the *Deutsch-Luxemburgische Bergwerks- und Hütten Aktien-Gesellschaft* (German-Luxemburg Mining & Metallurgical Company). At the dinner following this visit, Director-General Meier, who had already welcomed the American guests at the preceding banquet, made an interesting address, in which he sketched the conditions of the iron and steel industry of Luxemburg, and the means adopted in that region to meet them. Mr. Julian Kennedy, of Pittsburg, Pa., replied for the American Institute of Mining Engineers, with cordial acknowledgment of the improvements in practice effected at the famous establishment. Afternoon tea in the beautiful gardens of the residence of Director Meier concluded the day's programme.

In these great works, the most interesting point, perhaps, was the new gas-engine central station, in which there are already four 1,600-h.p. gas blowing-engines, and a fifth is now under erection, and ultimately a sixth and a seventh will be placed. The same building is to contain four 2,000-h.p. gas dynamos. It was in these works that the Grey rolling mill, mentioned in the sessions of the London meeting, was first installed.

The Visit to Hanover.

RECEPTION COMMITTEE.—Engineering Director A. Weiskopf (*Chairman*); Hon. Jay White, American Consul; Paul Schroeter, C.E., President of the Hanover Section of the German Society of Engineers; Dr. E. Laves, President of the Hanover Section of the German Society of Chemists; and Chief Engineer Urbach, President of the Hanover Electrotechnical Society.

Leaving Düsseldorf Saturday afternoon the party reached Hanover about sundown, and was quartered at the Hotel Kasten, where an informal reception took place in the evening.

On Sunday at 3 p.m., a festival dinner was held in the banqueting-hall of the hotel. Director Weiskopf welcomed the American guests, and offered toasts in honor of the Emperor of Germany and the President of the United States. Addresses were made also by Inspector Rasch, representing the

President of the Province, Mayor Eyle, representing the city, President Paul Schroeter of the Hanover Society of German Engineers, Engineer Schmidt of Hanover, Prof. Bauerman of London, and Mr. Charles Catlett (Staunton, Va.), Mr. E. S. Hutchinson (Newton, Pa.), and Secretary Raymond, A.I.M.E.

On Monday, the gentlemen visited the rolling-mills at Peine, and the furnaces and iron-mines of the Ilseder Hütte. Meanwhile, the ladies, convoyed by the charming and assiduous Ladies' Committee, were taken in automobiles through the beautiful streets of the city to the famous gardens and park of Herrenhausen, and were entertained at luncheon by Mrs. Director Weiskopf, in her residence.

At the Peine works, among the most celebrated in Germany, special attention was given to the Thomas (basic) open-hearth plant, the rolling-mill, and the extensive and elaborate villages, eating-houses, baths, hospitals, etc., for the benefit of the workmen. Similar features were studied with pleasure at Ilsede, where the party was entertained by Director Gerhard Meyer, and conducted by Dr. Crusius through the works, and afterwards to the company's Bülten iron-mines.

In the evening, a special meeting of the United Technical and Scientific Societies of Hanover was held in the Hotel Kasten. An interesting lecture, illustrated with lantern-views, delivered in English by Director-General Graessner of the German Potash Syndicate, on "The German Potash Industry," was followed by a discussion in both languages.

This industry, based upon the unique deposits of potash-salts in the Stassfurt region, is controlled by a powerful syndicate, in which the Prussian government is interested. The chief work of this syndicate (or "trust"), however, has not been to "put up prices," except so far as the maintenance of uniform prices has prevented a mad competition in the development of an over-supply of the market. What was most needed was an increase throughout the world of the demand for potash-salts; and this has been effected by the syndicate through its bureau of scientific experiment and what might be called scientific advertising—that is, intelligent co-operation with governments and institutions in all countries in experiments showing the immense value of the potash-salts as fertilizers, both in comparison with "nitrogenous" fertilizers, and as a complementary addition to them. Among the views shown by Director-General Graessner to illustrate this point, the most impressive were those which exhibited the reclamation of vast areas of barren moor in the great plain of northern Germany.

On Tuesday morning, under the guidance of Director Weiskopf, a visit was made to the alkali-mines and works at Ronnenberg, where a number of the party descended the 560-m. (1,837-ft.) shaft to the deposit of potash-salts.

SILVER LOVING CUP, PRESENTED TO PROFESSOR BENNETT H. BROUGH.

SILVER PUNCH BOWL, PRESENTED TO DR. E. SCHROEDTER.

SILVER FRUIT-DISH, PRESENTED TO MR. L. P. SIDNEY.

SILVER FLOWER-DISH, PRESENTED TO DR. A. WEISKOPF.

In addition to these official certificates, special testimonials have been sent by the members of the visiting party to Secretary Brough, Mr. Sidney, the Stewards of the British excursion, and Drs. Schroedter and Weiskopf, and Mr. Lemke, of the German Reception Committee, as shown in the accompanying illustrations.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Design of Blast-Furnace Gas-Engines in Belgium.*

BY PROFESSOR H. HUBERT, LIÈGE, BELGIUM.

(London Meeting, July, 1906.)

THE first attempts at direct utilization of blast-furnace gas in engines were made in 1895. For a considerable time the gas had been burnt in Cowper stoves for heating the blast for the furnace, and under the boilers which supplied steam to the blowing-engines, and others serving the furnaces. It was natural, therefore, that the idea of directly employing it in gas-engines should have occurred simultaneously to several engineers, notably to Lürmann and to Lencauchez, who had pointed out the blast-furnace as a powerful gas-producer. Nevertheless, nowhere had any attempt been made to apply it to this purpose up to the end of 1894, when Thwaite proposed it to Mr. James Riley, of the Glasgow Iron & Steel Company.

About the same time investigations were being made in Belgium and in Germany, independently of Thwaite's experiments, which were not generally known on the Continent.

The industrial world, which up to that time had hardly favored the idea, had thus been gradually prepared to receive it. The gas-engine, long restricted to small sizes and dependent upon the use of an expensive fuel obtainable only in large centers, now began to make headway.

At the Paris Exhibition of 1889 two engines of 100 h.p. were shown and excited much interest among engineers. One had four cylinders, and was made at the celebrated works of the Deutz Company, and the other was a single-cylinder engine, exhibited by two French designers, Messrs. Delamare-Deboutteville and Malandin.

In the meanwhile the design of gas-producers had made important progress, completely freeing the new engine from its

* Presented at the Joint Meeting of the Iron and Steel Institute and the American Institute of Mining Engineers, London, July, 1906, and here published under a mutual agreement between the Councils of the two Institutes.

dependence on the gas-works, enabling it to be installed anywhere, and to realize to the full extent its economic value by supplying it with a cheaper fuel.

In 1892 Delamare installed at the Moulins Leblanc Works at Pantin a four-cycle, single-acting, single-cylinder engine, using producer-gas, and developing 220 b.h.p., with a consumption of about 1 lb. of coal per b.h.p. per hr. Despite the difficulties met with in this bold attempt, it showed the possibility of economically producing high power with poor gas.

The time had now arrived for engineers to pay attention to the use of gas from blast-furnaces, which, although not of great heating value, was less costly; and was the more suitable on account of the progress which had been made in the design and working of blast-furnaces, the proportionally lower consumption of coke, and, as a result, the marked reduction in the relative quantity of combustible gases, which only sufficed, with difficulty, to heat the blast and to produce the steam required about the furnaces. Finally, the progress of the science of heat had brought to light the causes of the low thermal efficiency of the steam-engine, and notably of the loss resulting from the employment of boilers.

Therefore it is not surprising that the idea of dispensing with the boiler and burning the blast-furnace gases directly in the engine occurred, nearly simultaneously, in three countries, where metallurgical industry had made great progress.

To Messrs. Bailly and Kraft, of the Cockerill Company, belongs the honor of being the first in the field in Belgium. The patent taken out by the Cockerill Company for this new application was dated May 15, 1895, and the first trials were made at the end of that year. They were made with a simplex engine of 8 h.p., in which it had only been sought to reduce the clearance space, in order to increase the compression and to facilitate the ignition of the mixture. The gas cleaning was very imperfect, and was carried out simply by passing it through two scrubbers, 4 m. in height.

This engine displayed perfect elasticity, and adapted itself to the variations of composition, pressure and temperature of the gases, giving an efficiency of 77 per cent.

Messrs. Bailly and Kraft[1] described the results of the first trials, and the conditions necessary for the direct use of blast-furnace gases, showing that a plant producing 100 tons of pig-iron per day was able to furnish about 18,000 cu. m. of gas per hr. with a calorific value of 1,000 calories. Taking into consideration that half this volume is available, and allowing for an efficiency of only 20 per cent. in the engines, the authors snowed that it would be possible to obtain from these gases about 3,000 horse-power.

The small trial engine consumed about 5 cu. m. per b.h.p., which reduces the preceding figures to 1,800 h.p.; but they foresaw at the time that this consumption would be ere long greatly reduced, and that blowing-engines driven by gas would be built. They also foresaw that, by disposing of the great surplus motive power, the blast-furnace would ultimately become a center for the production of energy for works surrounding, the boilers of which it would gradually supersede.

This remarkable progress was described by Mr. E. P. Martin, President of the Iron and Steel Institute, in his Presidential Address of 1897.[2]

At the meeting of the Institute on May 3, 1898, M. A. Greiner discussed[3] the results published up to that time, which included my paper of February, 1897, a note by Galbraith and Rowden on November 18, 1897, one by Lencauchez on November 8, 1897, and another by Lürmann on Februry 27, 1898.

Mr. Greiner combated the objections which had been specially raised against this new method of employing gas by German metallurgists at the Düsseldorf meeting, and gave reasons for his belief that the consumption would be reduced below 4 cu. m. per b.h.p. per hr., and that the blast-furnace would be able, by superseding the steam boiler as an intermediary in the production of motive power, to place at the disposal of the engineer 20 h.p. per ton of pig produced daily.

Experience soon verified these forecasts. The Cockerill Company have constructed, with the collaboration of Mr. Delamare, a four-cycle, single-cylinder engine of the Simplex type, which, in the 24-hr. trials, at which I had the honor to

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[1] *Annales des Mines de Belgique*, 1897.

[2] *Journal of the Iron and Steel Institute*, vol. li., Mo. 1, pp. 19 to 40 (1897).

[3] *Journal of the Iron and Steel Institute*, vol. liii., No. 1, pp. 21 to 31 (1898).

collaborate with Professor A. Witz, gave 1 b.h.p. for an average consumption of 3.329 cu. m. of a gas possessing a calorific power of 981 calories—say 3,266 calories. (This figure has since been reduced to 3,162.)

The principal dimensions of this engine were: diameter of cylinder, 0.8 m.; stroke of piston, 1 m.; rev. per min., 105; i.h.p., 213; b.h.p., 182.

The construction of this engine is worthy of note. The cylinder proper is cast with a breech carrying at its lower portion the exhaust-valve, and at the back a cylindrical prolongation in which the admission-valve is placed. This breech or cylinder head has its own water-jacket, and is provided towards the front with flanges bolted to the cylinder jacket, which was a part of the cylinder bayonet casing.

The shaft is not cranked, and carries a heavy fly-wheel. The piston is made in one piece, and is not chilled. The pressure does not exceed 7 kg. The sparking is effected by Delamare's system, in which a succession of sparks, produced by a Ruhmkorff coil, is emitted from a slide-valve on the back of the cylinder when its opening comes opposite to an orifice bored in the back. The movement of the sliding-valve, and similarly of the other valves, is made by a crank and by cams keyed on to an auxiliary shaft, parallel to the cylinder and revolving at half the speed of the main shaft. The governing is effected by the hit-and-miss arrangement by means of Delamare's air governor.

Starting is effected by turning the fly-wheel, by a hand-wheel, and by admitting a charge of carbureted air, the explosion of which starts the engine.

The success of this engine, which worked perfectly without the gas being cleaned as effectively as is now done, and is still running after being eight years in service at Cockerill's, encouraged them to build a much more powerful type of engine capable of directly operating a blowing-apparatus of 600 h.p., and consequently of liberating the blast-furnace from its dependence upon the boiler.

Though the enterprise was considered rash, they still went on with the attempt, which was logically justified, seeing that in modern steam-driven blast-furnace installations the gas produced is only just sufficient for the requirements of the fur-

naces. To procure gas in excess it was necessary to commence by replacing the existing engines by the more economical gas-engines, for by such means only would gas be available. It is necessary to commence with gas-driven blowing-apparatus. A motor of this description attracted much attention at the Paris Universal Exhibition of 1900. Another, coupled with its blowing apparatus, in the blast-furnace department of Cockerill Company, and started up on November 20, 1899, was submitted to a series of trials on March 20 and 21, 1900.

The features of this remarkable engine were as follows: regulation by the method of "hit and miss," that is to say, suppression of an admission of gas complete; diameter of cylinder, 1.300 m.; stroke of piston, 1.400 m.; rev. per min., 94.4.

By brake tests.	Indicated horse-power, ...	786	with 89 p. ct. admission and 11 p. ct. "hit and miss" by the governor.
	Effective brake horse-power, . . .	575	
	Consumption per indicated horse-power hour,	2.556 cu. m. or 2,515 calories.	
	Consumption per brake horse-power hour, .	3.495 cu. m. or 3,440 calories.	
Tests with the blowing apparatus.	Number of revolutions per minute, . .	93	
	Indicated horse-power, ...	886.5	full charge without "hit and miss."
	Effective brake horse-power, . . .	725	
	Consumption per indicated horse-power hour,	2.334 cu. m. or 2,343 calories.	
	Consumption per brake horse-power hour, .	2.853 cu. m. or 2,864 calories.	

The method of construction of the 200-h.p. motor had generally been retained, saving that the main bearings were separated from the cylinder casing, and were connected by four strong screwed steel stay-bolts, giving easy access to the piston. The shaft was cranked and rested on three bearings to support the fly-wheel, which weighed 33 tons. The piston-rod traversed the back space in a stuffing-box.

The admission-valves were retained below like those of the exhaust. The admission of gas was carried out by separate valves placed in a valve-box, separated from the cylinder by a third valve called the mixture-valve. The methods of working the valves and those of the ignition slide-valve were retained. The regulation was carried out by "hit-and-miss." The pressure attained 9 kg. per sq. cm. The circulation of water extended to the head and to the piston-rod itself, to which the water penetrated by means of flexible pipes, which

adapted themselves to its movement. The exhaust-valve was also cooled. This was done with the object of preventing the ignition of the mixture by the dust, which, combining with the products of the decomposed oils on the piston or in the recesses of the explosion-chamber, might form concretions retaining a temperature high enough to ignite the gases.

The arrangement of all the valves at the under-side of the cylinder was such as to facilitate the sweeping out of the dust and decomposed oil, and to allow these large engines to work equally as well as the 200-h.p. engines without having recourse to a more perfect gas-cleaning process. This hope was ill-founded. It became necessary to interpose, between the blast-furnace and the large engines of this class, apparatus capable of reducing the dust held in suspension by the gas to 0.02 g. per cu. m. The means now used in Belgium are centrifugal fans with water injection, and Theisen, Brian, and Zchokke apparatus. The latter are not, strictly speaking, purifiers; they are rather coolers.

As they are not the invention of Belgian engineers, and as they will be made the subject of another paper, it is not necessary to deal further with them.

As is well known, the novel idea of the Cockerill Company was vigorously discussed by engineers, who saw therein an economic mistake, and maintained that it was better to divide the power between two or four cylinders. The designers, nevertheless, knew perfectly well that they could obtain in this way, for a 600-h.p. engine, a more regular and perhaps more economical engine. They had already, however, studied the two-cylinder tandem types of 600 and 1,200 h.p. One of Cockerill's licensees, Messrs. Breitfeld, Danek of Prague, had since 1901 constructed a four-cylinder, double tandem engine of 600 h.p. giving remarkably even running; but Messrs. Cockerill wished to demonstrate that it was practically possible to develop 600 h.p. by means of a single cylinder alone, single acting and of four cycles, and consequently to construct engines developing up to 2,500 h.p. without exceeding four cylinders. In addition to this they were, moreover, anxious also to improve the governing, by applying to these large engines the principle of variable admission in lieu of the hit-and-miss governing, which required the use of heavy fly-wheels, and was

not well suited for producing alternating electric currents, and needlessly strained the engine when it had to run continuously with reduced loads.

From 1901 they realized with M. Delamare that it was essential to obtain a variable-admission motor, an air-governor, or else a centrifugal force, causing the double air- and gas-valves to open from the commencement of the suction-stroke, but determining the closure earlier in the stroke as the power to be developed becomes lower.

In this manner the mixture admitted possessed the composition most favorable for complete combustion, but the volume admitted to the cylinder varied, and with it the pressure.

The ingenious mechanism which realized this mode of operation I have described elsewhere;[4] it was applied to a single-cylinder motor of 200 h.p. of the same dimensions as that of 1898.

The trials to which it was submitted in November and December, 1901, established beyond doubt a consumption varying between 3.318 and 3.455 cu. m. per b.h.p. per hr. for full load, the calorific value being from 914 to 1,017 calories. The expenditure in calories per h.p. varied between 3,172, and 3,434, and has been on an average nearly 3,298; practically the same as that of 1898. At half-load it was, on an average, 4,320 calories, and at quarter-load 7,406 calories.

About the same time (1902) the Cockerill Company produced another engine, designed to give greater regularity with smaller dimensions,—viz., the double-acting engine.

It was well known that the first industrial gas-engine, that of Lenoir, was double-acting, but the success of the Otto four-cycle and single-acting engine had, for a long time, relegated to the background all other types of engines. Nevertheless, M. Letombe, at the Brussels Exhibition, showed a four-cycle and double-acting engine.

The Körting Company exhibited at Düsseldorf a powerful two-cycle, double-acting engine, which attracted much attention. The long-standing prejudice against the adoption of this system was thus broken down.

The direct driving of the blowing-apparatus from the piston-

[4] *Revue Universelle des Mines*, vol. lix., pp. 273 to 329 (1902).

rod of the engine had accustomed Cockerill's engineers to the adoption of a stuffing-box at the back end of the cylinder. They were, therefore, naturally disposed to adopt double action, which enabled them to considerably reduce the size of the cylinder, and consequently approach large powers more easily, thus insuring more steady running with a lighter fly-wheel.

They retained, firstly, the general arrangement of the single-acting motor, which up to that time they had constructed, notably the disposition of the inlet- and exhaust-valves underneath the cylinder. However, from that time they introduced an important modification. The cylinder-liner, with its jacket, constituted a part independent of the two cylinder-heads. Each of these carried a stuffing-box, through which the water-cooled piston-rod worked, and an extension downwards of the combustion-chamber, in which were installed the valve, which simultaneously admits air and gas and actuates the exhaust-valve. The actuating mechanism of the valves was also modified, without departing from the system of variation of the admission, consisting of cutting off the air and gas supply simultaneously. This system had the advantage of preserving the composition of mixture most favorable to complete combustion, but it had the inconvenience of diminishing, to some extent, the compression as the charge decreased. This diminution reduced the economic efficiency of the engine in the case of light loads, and also when it happened that the gas was very poor it spoilt the ignition and caused misfires, which altogether upset regularity and economy.

This trouble becomes very marked in motors driving dynamos, which very often work with reduced loads, and where economy is a greater consideration than in blowing-engines. Therefore, no time was lost in introducing another system of variation, consisting of air-admission to the cylinder during the whole piston stroke, and only allowing the gas to enter during the last portion of the stroke by the governor varying the moment at which this admission commences. In this way invariable compression is secured.

It is true that when the mixture is modified it becomes poorer and poorer; but it should be noted that gas is introduced at the back-end of a cylinder already partly filled by a

volume of air which follows the piston. Although it is impossible absolutely to rely upon retaining the exact stratification characteristic of the Otto cycle, there persists, nevertheless, an undoubted stratification of mixture, the richest strata remaining at the back-end of the cylinder, close to the igniter.

The sparks then impinge on the explosion-mixture, which, being strongly compressed, insures that the ignition is readily transmitted to the whole volume. It will be seen that the gas-admission valve should be able to move independently of that giving air admission.

In engines of this system the two valves are superposed, the air arriving by a casing which surrounds the gas-passage, and the valve spindle passing through the gas-valve, which is hollow. The placing of the valves in an antechamber of the combustion-chamber, leading to a tubular combustion-chamber, evidently assists the stratification of which mention has been made, and consequently the ignition of weak charges, but it resulted in cylinder-heads of unsymmetrical form, which created difficulties at Cockerill's works, as it had already done elsewhere.

The unequal contraction of the metal of the various parts of the cylinder-head caused great stress, which, added to the already high stresses, due to the explosion and to the heating, has occasionally brought about the fracture of the cylinder-heads, even when they have been replaced by steel-castings.

This circumstance decided the makers of large engines to revert to the symmetric arrangement of the valves, which is customary in steam-engines, where the inlet-valve is placed on the top of the cylinder and that of the exhaust underneath, and thus to obtain an arrangement which lends itself well to expansion, and which, moreover, facilitates access to the valves.

This arrangement has been obtained in different ways by manufacturers, notably at the works of Deutz and Nürnberg and at Seraing. At the Cockerill Company's works the covers are no longer attached to the central body by studs screwed into it, but joined by tie-bolts bolted to flanges on these covers.

These bolts are thus subjected to tension, and, similarly, the body of the cylinder is subjected to a compression stress of the kind which best suits such metal. This arrangement, shown in Fig. 1, is patented. The frame is formed of two box-

girders carrying the cylinder. These girders are joined by tie-bolts to others that contain the slides and carry the crank-shaft bearing. The piston is composed of two halves with double walls, each half permitting water-circulation, the two halves being bolted together with an india-rubber joint.

The water cooling is effected at a pressure of from 3.5 to 5 kg. per sq. cm. to avoid water-hammering in the piston and its rod. The water, furnished to the latter by a duct fixed at one end, passes through the rod and the two halves of the piston, and goes out at the back by another duct.

The ignition is effected by means of one or two high-tension magnetos, through fixed sparking-plugs. These magnetos do away with the necessity for a source of electricity external to the motor. The compression has been successively increased up to 14 kg. per sq. cm. The starting is effected by means of air, compressed to 10 atmospheres by a special compressor, and retained in a reservoir in sufficient quantity to enable the engine to revolve several times.

The assembling of the parts, which constitutes one of the features of this motor, must now be described. As shown in Fig. 2, the usual arrangement of the auxiliary side shaft, parallel to the cylinder axes, and actuated by the main shaft by means of gearing in the ratio of 1:2, is retained. On this auxiliary shaft, B, are keyed the cams, C, which actuate the opening of the inlet and exhaust valves.

The exhaust valve, E, opens a little before the end of the stroke, but always at the same moment in each stroke; it is worked by the cam, C′, by means of a lever and a rod carrying a roller at its lower end. The exhaust-valve is hollow, and likewise the spindle, to permit of the circulation of cooling-water.

The inlet distributor consists of two valves: one for gas, the other for air and the mixture. The spindle of the latter passes through the hollow spindle of the gas-valve. Both are constantly brought back to their seats by springs placed in a box above. The air-valve is double. It consists of a solid single-seated flap valve opening downwards, and a hollow perforated sleeve valve, L. These two parts are attached to the same spindle and move simultaneously.

From a little in advance of the commencement of the suction

stroke, the double valve is lowered by the lever, D, actuated by the rod, *t*, at the lower end of which works the cam, C. By this movement the openings of the sleeve-valve, L, are brought opposite the ports formed in the casing, by which the incoming air arrives. The latter is thus drawn in from the commencement of the piston-stroke and throughout its entire duration.

To the lever, D, is attached a spindle, F, which works a second lever, K, the function of which is to lower the double-seated gas-valve, M. If this spindle was unalterable in length, the two levers, D and K, would work simultaneously, and the gas would pass into the cylinder simultaneously with the air. But the spindle, F, is composed of two parts, of which one carries the piston and the other the cylinder of a dash-pot, P.

The upper part is thus able to rise up, expanding the air in the cylinder, provided that the lower portion remains fixed, and in this case the gas-valve does not open. The end of the lever is locked during the period of exhaust by a finger, H, which keeps it from moving as long as the finger remains vertical. If this part is moved to the right the lever, K, now becomes free, but the descent of the spindle of the mixing-valve, A, compresses the spring, R, placed upon that of the gas valve, M, as long as this is immovable. Immediately K is unlocked, this spring is able rapidly to lower M, causing the valves to resume their original distance. The shock is deadened by the dash-pot, and the spindle, F, likewise resumes its normal length.

From this time forward the gas penetrates, with the air, into the cylinder, constituting the explosive mixture, which will be afterwards compressed, and ignited by the spark. In order, therefore, to enable the admission of gas to be varied, it suffices to operate at the moment the lever, K, is unlocked. This instant is determined by the governor in the following manner: The finger, H, is articulated on a shaft, N, from whence it is prolonged to engage a spring, which tends to keep it constantly locked with K.

Its lower extremity, I, carries a roller, on which is taken the thrust of the cam, V, fixed on the oscillating shaft, X. It is this cam which produces the unlocking of K, by pushing against I, and turning aside H, despite the resistance of *a*.

The oscillating movement of X is produced by a rod, *b*, which operates the crank, *m*, keyed on X. The rod is attached to one

end of a transmitting lever, Z, the other end of which is worked by an eccentric, *o*, keyed upon the auxiliary shaft, B. The lever, Z, however, constitutes an extension of the roller of an eccentric-strap, T, of which the sheave is keyed on the spindle, W. This carries a crank joined by a rocking-beam to the centrifugal governor-socket. The movements of the governor-socket thus modify the position of the shaft, W, and consequently the center around which Z oscillates. This results in an alteration in the proportion of the two arms of this lever, and, as a result, the length of travel of the connecting-rod, *b*, and increases the oscillation of X. It may be seen, therefore, that the moment at which the gas-valve opens is thus determined by the governor, which retards or advances it according as the speed of the engine increases or diminishes.

When, as a result of the rotation of the shaft, B, the cam, C, ceases to operate the connecting-rod, *t*, the springs mounted upon the spindles of the two valves bring the latter back to their seats. It will be seen from this that, as a result of the clearance between the parts, or from the expansions, the gas-valve closes first, leaving open the mixture-valve. This hinders the compression. To avoid this inconvenience the spring of the gas-valve is made weaker than the other, so that it is able, despite the arrest of the former, to replace the latter on its seat, by slightly compressing the first spring.

To this somewhat lengthy description of what is really a simple mechanism, and works perfectly, it may be added that the exhaust commences about 15 per cent. in advance, and is prolonged a little beyond the finish of the stroke, during which time the admission has slightly commenced. The result is that the exhaust still continues. At this juncture the burnt gases have attained a high velocity, which causes a powerful suction in the cylinder.

The atmospheric air rushes violently into the explosion-chamber, completely sweeping out the burnt gaseous residuals, which would hang in the vicinity of the sparking-plug and tend to spoil the ignition of the mixture.

The application of this ingenious mechanism confers on the double-acting engine very even running, allowing alternators of 50 periods easily to be coupled in parallel.

This type, studied by the Cockerill Company since 1904, was

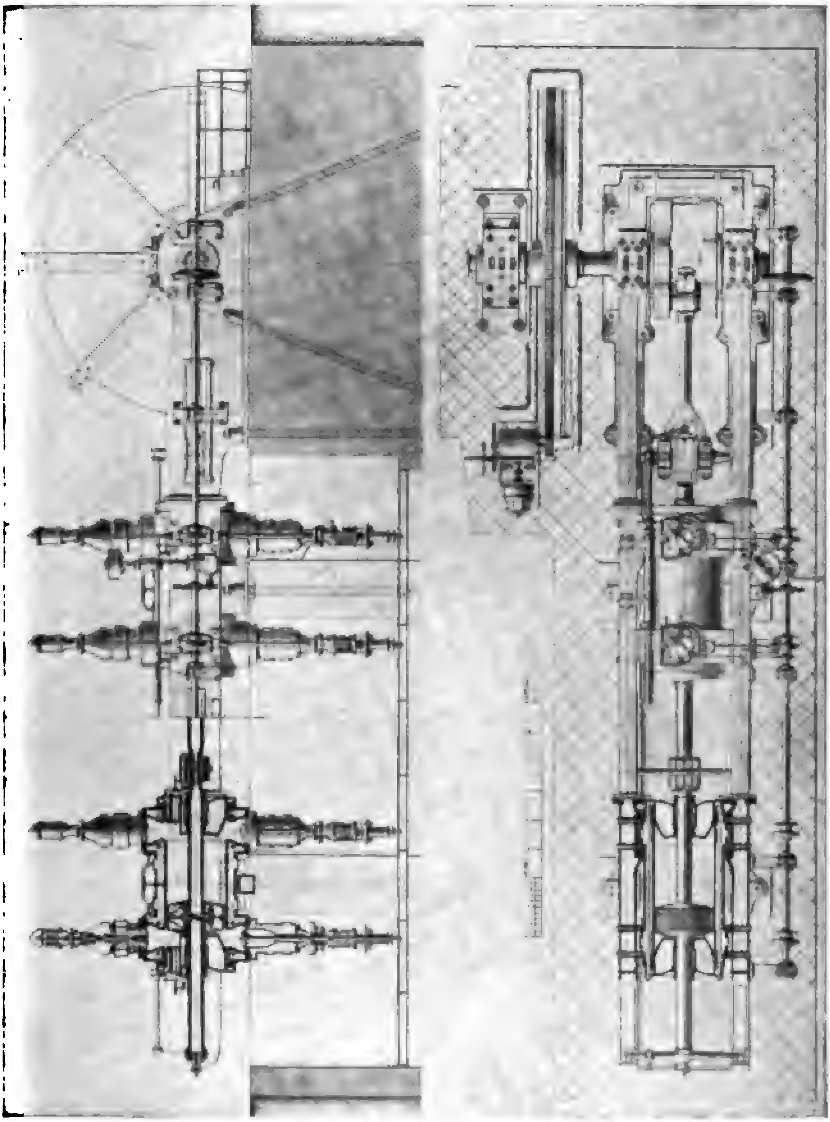

FIG. 1.—VALVE ARRANGEMENT OF THE COCKERILL ENGINE.

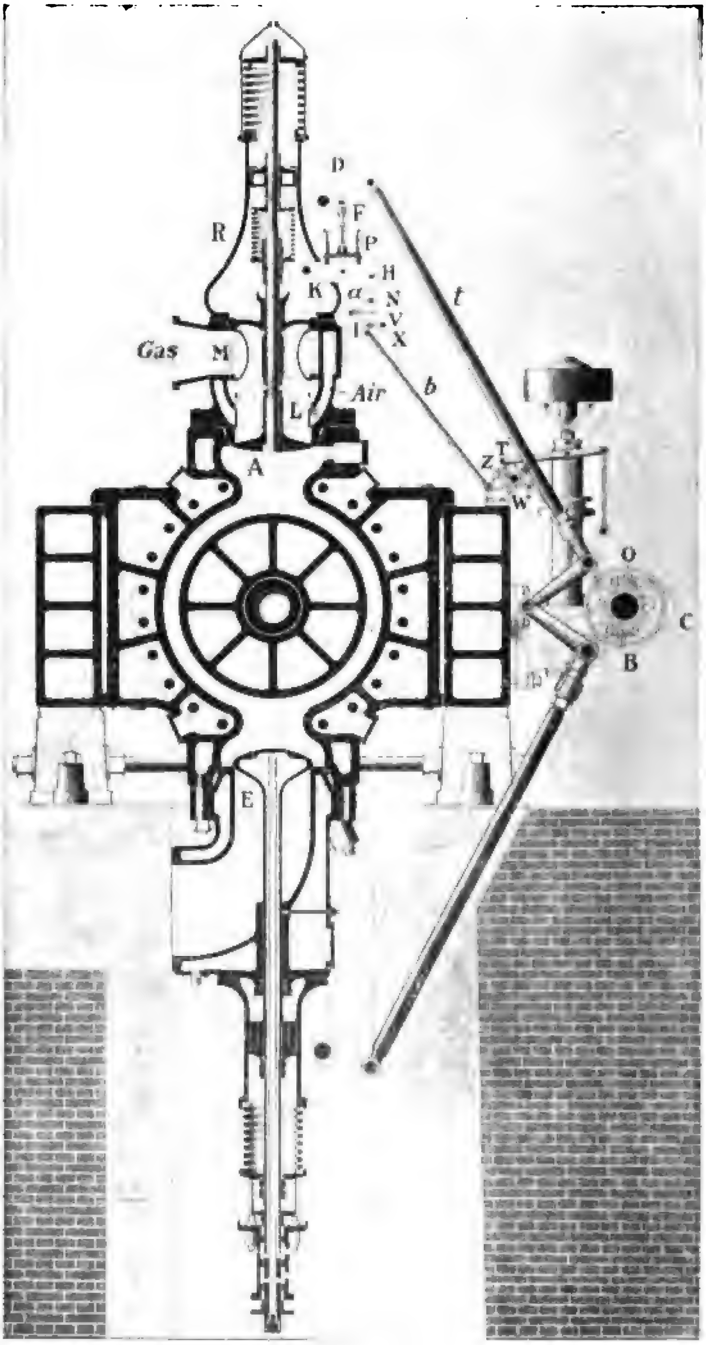

FIG. 2.—ARRANGEMENT OF PARTS OF THE COCKERILL ENGINE.

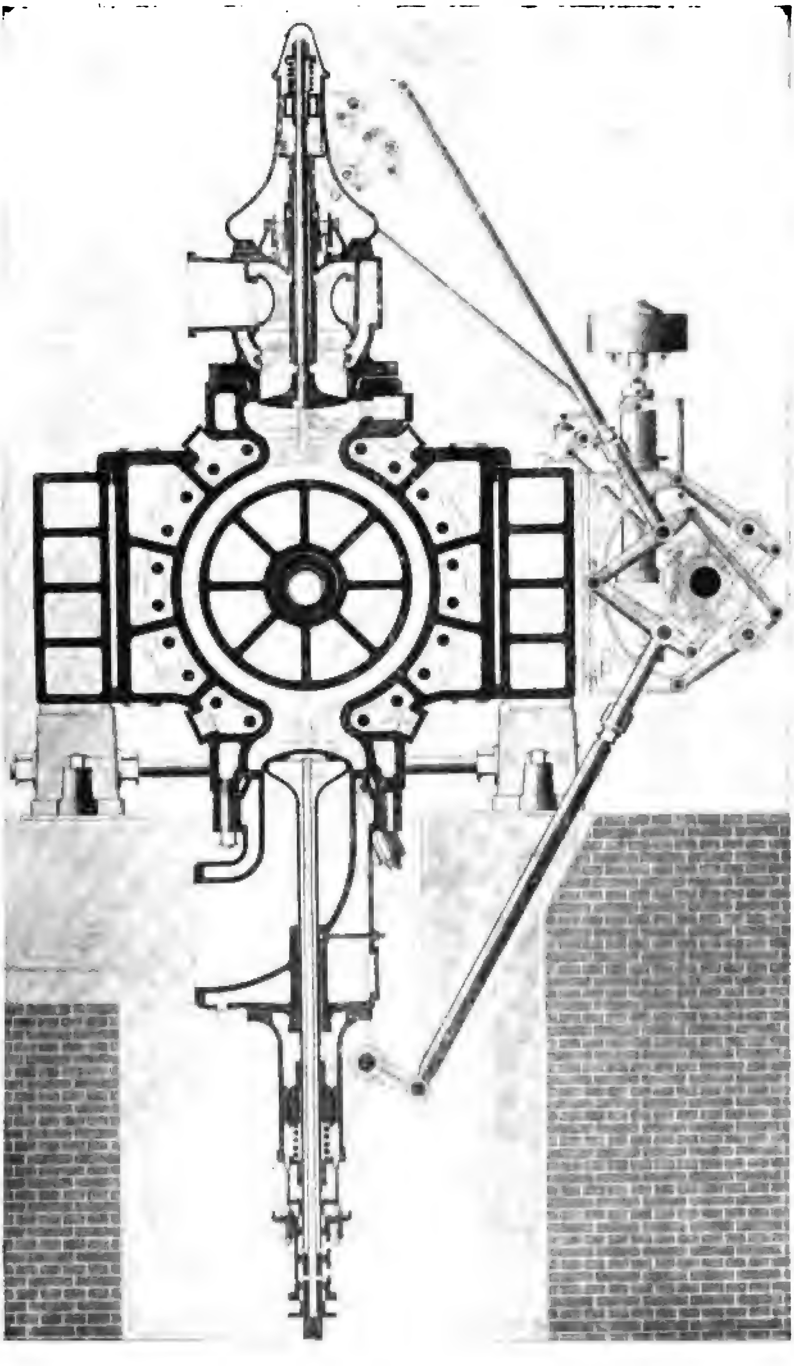

FIG. 3.—SPECIAL VALVE ARRANGEMENT OF THE COCKERILL ENGINE.

FIG. 4.—NEW TYPE OF THE COCKERILL ENGINE.

put in service on a two-cylinder tandem-engine of 1,400 h.p., installed in the electricity department of the company.

The pistons are 1 m. in diameter by 1.1 m. stroke. The shaft makes about 100 rev. per min., and carries a fly-wheel of 26 tons, and drives a continuous-current dynamo.

Engines of this class are made of 500 h.p. (600 mm. × 800 mm. × 135 rev. per min.), of 750 h.p. (750 mm. × 900 mm. × 100 rev. per min.), and of 1,400 h.p. (1,000 mm. × 1,100 mm. × 100 rev. per min.).

The Cockerill Company have also constructed a single cylinder engine of 575 h.p. (1 m. × 1.100 m. × 80 rev. per min.), one of 1,000 h.p. (1.150 m. × 1.250 m. × 80 rev. per min.), and one of 1,300 h.p. (1.300 m. × 1.400 m. × — per min.

However, for this special purpose, the constant compression, necessary for the economical production of electricity, might become troublesome when the engine is of the single cylinder type.

It happens, indeed, that the blowing-apparatus may be perceptibly slowed down, and then it might be that the centrifugal force of the fly-wheel would be insufficient for passing the dead-center at the time of compression, especially if a miss-fire had just previously taken place.

It is advantageous, in this case, to do away with constant compression and revert to variable quantity admission, of a mixture of constant composition (Fig. 3 shows this arrangement). This is a little more complicated than the other, and has been worked out for two types—one of 575 h.p. (1 m. × 1.10 m. × 80 rev. per min.), and the other of 1,300 h.p. (1.300 m. × 1.900 m. × 80 rev. per min.).

It is interesting to be able to compare the economy of the new type of engine (Fig. 4) with those of the preceding types already referred to.

The Cockerill Company instructed me to undertake, with Professor Witz, detailed tests on the 1,400-h.p. two-cylinder double-acting and tandem engine installed in their electric service. These tests were made on January 9 and 10, 1906. Arrangements were made for measuring the consumption, a bell, holding about 300 cu. m., being provided for this purpose.

As the engine working at full load consumes about 2.5 cu. m.

TABLE I.—*Results of Tests on the 1,400-h.p. Two-Cylinder Double-Acting and Tandem Engine.*

Description of Test.	Indicated Horse-power.	Brake Horse-power.	Electrical Horse-power.	Mechanical Efficiency, Per Cent.	Electrical Efficiency, Per Cent.	Total Efficiency, Per Cent.	Consumption per Hour and per Horse-power (*cheval*) in Cubic Meters, at 0.02760 Millimeter per			Highest Calorific Power by the Witz Bomb per 3 Meters. Calories.*	Calories Used per Hour and per			Thermal Efficiency Per Cent.	Heat Carried Away by	
							Indicated Horse-power.	Brake Horse-power.	Electrical Horse-power.		Indicated Horse-power.	Brake Horse-power.	Electrical Horse-power.		The Water of Circulation, Per Cent.	The Exhaust Gas.
½ load......	1250.48	986.00	917.5	78.7	93.1	73.3	2.513	3.187	3.425	979	2460.2	3120.1	3353.1	29.82	16	
¾ load......	1463.88	1333.2	1250.7	91.10	93.8	85.4	2.313	2.540	2.707	963	2227.4	2446.0	2606.8	28.52	16.2	
Full load.	1569.45	1466.15	1377.45	93.41	93.9	87.76	2.247	2.406	2.560	983	2208.8	2365.1	2516.5	28.77	20.2	
Full load.	1607.74	1494.8	1404.7	92.97	94.0	87.4	2.325	2.497	2.657	943	2192.5	2254.7	2505.6	28.98		
Overload..	1755.06	1581.9	1487.7	90.00	94.0	84.7	2.155	2.352?	2.542	988	2129.1	2363.3	2511.5	29.84	20.2	

* This is greater than that given by the Junkers calorimeter.

per h.p. per hr., the bell was only able to feed it for a little more than 5 min. It was then raised again by the gas being pumped into it by an electric rotary-pump. In the interval, the opening of gas-valves allowed the engine to take gas directly from the main, from which these gas-valves isolated it during the time of the trials.

The indicated work (i.h.p.) was determined by a large number of diagrams, taken by two observers. The useful work (effective horse-power, b.h.p.) was ascertained by means of the electric energy developed by a dynamo, of which the output had been carefully tested in advance for a series of powers. Samples of the gas were taken, for the determination of the calorific power, by the Witz bomb, in the laboratory of Professor Witz at Lille University. The quantities of water used in cooling the different parts of the engine were measured, as well as their temperatures. It was not found practicable to take the gas at the outlet, because the water injected into the exhaust vaporized instantly and lowered the temperature.

The detailed results of these tests will be published later; but the principal elements, enabling the progress made since the commencement of this novel application of blast-furnace gases, and the enormous economy it has brought about, to be measured, are given in Table I.

It is interesting to compare the results obtained by these trials with those obtained previously with engines made by the same company.

The figures, given in Table II., are significant. In comparing the trials of 1906 with those of 1900, which gave results which were considered excellent at that time, there was found a diminution of 15 per cent. of calories used per i.h.p. For the b.h.p. the reduction attains 31.4 per cent. Finally, the thermal efficiency has been increased 18.4 per cent. The advance made is thus very considerable. The advantage obtained, as compared with the employment of steam, is by no means the least interesting of facts brought out by this investigation. Admitting, however, that a 70-per cent. efficiency is obtained by burning the gases under boilers, which is considered satisfactory, and that the steam raised amounts, according to Carnot's cycle, to an efficiency of 40 per cent. (between 200° and 10°, which the cycle of Rankine makes 77 per cent. of that of Car-

TABLE II.—*Results of Former Tests Compared with Tests on* 1,400-*h.p. Two-Cylinder Double-Acting and Tandem Engine.*

No.	Description.	Date of Trials.	Power.		Consumption of Gas.		Consumption of Heat.		Thermal Efficiency.
			I. H. P.	B. H. P.	I. H. P.	B. H. P.	I. H. P.	B. H. P.	Per Cent.
1.	*8 Horse-Power Engine.*	1896	5.26	4	4.03	5.30	4030	5300	15.77
2.	*200 Horse-Power Engine.* Single cylinder, single-acting, constant admission.	July 19–20, 1898	213.9	181.82	2.830	3.329	2775.8	3625.7	22.9
3.	*600 Horse-Power Engine.* Single cylinder, single-acting, constant admission.	March 20th, 1900	825.8	670.0	2.560	3.156	2520.1	3106.8	25.2
4.	*200 Horse-Power Engine.* Single cylinder, single-acting, variable admission.	Dec. 2d, 1901	246.9	215.3	2.981	3.418	2766	3172	23.0
5.	*1400 Horse-Power Engine.* Double-acting, tandem, variable admission.	Jan. 9 & 10, 1906	1755.06	1581.9	2.155	2.392?	2129.1	2363.3	29.84

not), and finally that one could succeed in obtaining 80 per cent. of the Rankine cycle, the thermal efficiency becomes

$$0.70 \times 0.40 \times 0.77 \times 0.8 \times 100 = 17.25$$

which is lower, by 42 per cent., than that of the motor above described.

It has been assumed, earlier in the paper, that a blast-furnace producing 100 tons of pig-iron per day produces about 9,000 cu. m. of gas at 1,000 calories, available for the production of power.

Under these conditions, by obtaining 2,450 h.p. with the steam-engine, and 4,220 h.p. by using the gas direct in gas-engines, there remains a difference of 1,770 h.p. in favor of this new application over the results obtained by a first-class steam-plant of the usual (boiler) type.

These figures explain the success obtained in metallurgy by the direct use of blast-furnace gas.

Besides the Cockerill Company there is but one other company (the Société de Saint Leonard) which has undertaken the construction of blast-furnace gas-engines. This company, which has acquired licenses for the construction of the Körting two-cycle double-acting engine, exhibited an engine of this class at

TABLE III.—"*Cockerill*" *Type Gas-Engines at Work or Building.*

I. H. P.	Type.	Driving.	Built for	Working Since
260	Single Cyl.	Dynamo.	Société Anonyme John Cockerill, Seraing, Belgium.	Mar., 1896
260	Single Cyl.	Dynamo.	Roechlingsche Eisen- u. Stahlwerke, Carlshütte.	Jan., 1899
800	Single Cyl.	Blowing Cyl.	Société Anonyme John Cockerill, Seraing.	Nov., 1899
800	Single Cyl.	Blowing Cyl.	Differdinger Hütte (Differdange).	Nov., 1899
800	Single Cyl.	Blowing Cyl.	Differdinger Hütte (Differdange).	Apr., 1900
800	Single Cyl.	Blowing Cyl.	Paris Exhibition and Cockerill Works.	May, 1900
800	Single Cyl.	Blowing Cyl. & Dynamo.	Hütte Aumetz Friede, Lothringen.	May, 1900
800	Single Cyl.	Dynamo.	Differdinger Hütte (Differdange).	Aug., 1900
800	Single Cyl.	Blowing Cyl.	Differdinger Hütte (Differdange).	Aug., 1900
800	Single Cyl.	Blowing Cyl. & Dynamo.	Differdinger Hütte (Differdange).	Aug., 1900
800	Single Cyl.	Dynamo.	Differdinger Hütte (Differdange).	Oct., 1900
800	Single Cyl.	Blowing Cyl.	Differdinger Hütte (Differdange).	Jan., 1901
800	Single Cyl.	Dynamo,	Rheinische Stahlwerke, Ruhrort, Germany.	Mar., 1901
800	Single Cyl.	Dynamo.	Differdinger Hütte (Differdange).	July, 1901
800	Single Cyl.	Blowing Cyl.	Cochrane & Co., Middlesbrough, England.	Nov., 1901
800	Single Cyl.	Blowing Cyl.	Roechlingsche Eisen- u. Stahlwerke, Volklingen.	Jan., 1902
800	Single Cyl.	Blowing Cyl.	Roechlingsche Eisen- u. Stahlwerke, Volklingen.	Jan., 1902
800	Single Cyl.	Blowing Cyl.	Société Ougrée Marihaye, Ougrée, Belgium.	Feb., 1902
800	Single Cyl.	Dynamo.	Société Ougrée Marihaye, Ougrée, Belgium.	Feb., 1902
800	Tandem.	Dynamo.	Société Anonyme John Cockerill, Seraing.	Mar., 1902
260	Single Cyl.	Dynamo.	Société Anonyme John Cockerill, Seraing.	Mar., 1902
800	Single Cyl.	Blowing Cyl.	Aachener Hüttenverein, Esch.	May, 1902
800	Single Cyl.	Blowing Cyl.	Aachener Hüttenverein, Esch.	May, 1902
800	Tandem.	Dynamo.	Société Anonyme John Cockerill, Seraing.	June, 1902
800	Single Cyl.	Blowing Cyl.	Société Anonyme John Cockerill, Seraing.	June, 1902
125	Single Cyl.	Pumps.	De Wendel, Noyeuvre.	Apr., 1903
1600	Tandem.	Blowing Cyl.	Roechlingsche Eisen- u. Stahlwerke, Carlshütte.	Nov., 1902
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Société Anonyme John Cockerill, Seraing.	Oct., 1903
125	Single Cyl.	Power.	Société Anonyme John Cockerill, Seraing.	Dec., 1903
1600	Tandem, Double-Acting.	Dynamo.	Société Ougrée Marihaye, Ougrée.	Dec., 1903
800	Single Cyl.	Blowing Cyl.	Société Ougrée Marihaye, Ougrée.	Building.
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Société Dnieprovienne du Nidi de la Russie à Kamenskoic.	Building.
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Société Dnieprovienne du Nidi de la Russie à Kamenskoic.	Building.
1600	Tandem, Double-Acting.	Dynamo.	Société Anonyme John Cockerill, Seraing.	June, 1904
1600	Tandem.	Blowing Cyl.	Société de Vezin Aulnoye, Homecourt.	May, 1904
650	Tandem, Double-Acting.	Dynamo.	Usine de Bogoslowsk, Russie.	Apr., 1905
650	Tandem, Double-Acting.	Dynamo.	Usine de Bogoslowsk, Russie.	Apr., 1905
2000	Single Cyl., Double-Acting.	Blowing Cyl.	Société Minière d'Elba, Porto Ferrais.	Mar., 1905
1600	Tandem, Double-Acting.	Dynamo.	Société Anonyme John Cockerill, Seraing.	Mar., 1904
1600	Tandem, Double-Acting.	Dynamo.	Exposition Universelle de Liège, 1905.	Built May, 1905
650	Twin, Double-Acting.	Dynamo.	Exposition Universelle de Liège, 1905.	
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Cie des Forges et Acieries de la Marine, de et à Homecourt.	Building.
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Cie des Forges et Acieries de la Marine, de et à Homecourt.	Building.
1600	Tandem, Double-Acting.	Dynamo.	Société Ougrée Marihaye, Ougrée.	Building.
1600	Tandem, Double-Acting.	Dynamo.	Société de la Providence, Marchienne-au-Pont.	Building.
700	Single Cyl., Double-Acting.	Blowing Cyl.	Société de la Providence, Marchienne-au-Pont.	Building.
700	Single Cyl., Double-Acting.	Blowing Cyl.	Société Métal, Donetz Juriewka, Juriewka.	Building.
700	Single Cyl., Double-Acting.	Blowing Cyl.	Société Métal, Donetz Juriewka, Juriewka.	Building.
700	Single Cyl., Double-Acting.	Blowing Cyl.	Société des Acieries de France, Isbergues.	Building.
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Société Anonyme John Cockerill, Seraing.	Building.
125	Single Cyl., Double-Acting.	Pumping.	Société Ougrée Marihaye, Ougrée.	July, 1903
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Aachener Hütten Verein.	Building.
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Aachener Hütten Verein.	Building.
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Aachener Hütten Verein.	Building.

the Liège Exhibition. It is installing two engines of this type at the blast-furnaces of Grivegnée, but the results have not, as yet, been made public.

Appendix I.

The progress made in the design and construction of blast-furnace engines can best be seen by the list of engines given in Tables III. and IV., which, up to the present time, have been built, or are building, by the Cockerill Company.

Table IV.—*Additional Orders for "Cockerill" Type Gas-Engines.*

I. H. P.	Type.	Driving.	Building for
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Compagnie des Forges & Acieries de la Marine & à Homecourt.
1600	Single Cyl., Double-Acting.	Blowing Cyl.	Compagnie des Forges & Acieries de la Marine & à Homecourt.
700	Single Cyl., Double-Acting.	Blowing Cyl.	La Société des Forges de la Providence, Marchienne-au-Pont.
700	Single Cyl., Double-Acting.	Blowing Cyl.	La Société des Forges de la Providence, Marchienne-au-Pont.
1800	Tandem, Double-Acting.	Dynamo.	La Société des Forges de la Providence, Marchienne-au-Pont.
1800	Tandem, Double-Acting.	Dynamo.	La Société des Forges de la Providence, Marchienne-au-Pont.
850	Single Cyl., Double-Acting.	Blowing Cyl.	Société Ougrée Marihaye, Ougrée.
300	Vertical Twin, Double-Acting.	Dynamo.	Société Usines Maltzoff, St. Petersburg.
300	Vertical Twin, Double-Acting.	Dynamo.	Société Usines Maltzoff, St. Petersburg.

Appendix II.

In addition to the engines enumerated in Appendix I., the following engines have been built, or are building, at the works enumerated, under licenses from the Cockerill Company:

Table V.—*Additional "Cockerill" Engines being built under license from the Cockerill Company.*

Name of Firm.	No. of Engines.	Aggregate I. H. P.
Richardsons, Westgarth & Co., Ltd	24	19,650
Schneider & Co	15	7,880
Société Alsacienne	10	8,250
Société Française des Constructions Méchaniques	8	7,200
The Markische Maschinenbauanstalt in Wetter a. d. Ruhr	13	15,780
Breitfeld, Danck & Co., Karolinenthal	10	6,660
Elsässische Maschinen Fabrik, Mülhausen	33	38,130

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Influence of Silicon and Graphite on the Open-Hearth Process.*

BY ALEX. S. THOMAS, CARDIFF, WALES.

(London Meeting, July, 1906.)

HOWEVER good a furnace may be in regard to design, etc., or however excellent in the quality of the gas used, a suitable heat for the successful working of the metal cannot be obtained unless the melt be coated with a proper quantity of slag. This coating may be excessive or it may be deficient in quantity. The right degree of heat is the essential condition of successful working, for the quality of the steel made is never very good when the metal is allowed to simmer in the furnace for an excessive period, and this heat cannot be obtained if the metal is not protected by a proper covering of slag. This is not only to prevent the metal being over-oxidized and wasted, but also to prevent the metal being chilled when exposed with only a thin covering of slag.

The slag may be obtained in either of two ways: 1, naturally, by the presence of sufficient silicon in the iron used, to unite with iron oxide to form a staple slag; or, 2, by the addition of slag or free silica. In the first case the slag is formed naturally by the action of the oxygen in the flame—*i.e.*, the oxidizing atmosphere of the furnace—on the silicon in the metal when melting. The charge then melts, as it is termed, "thick," and protects the banks from being cut.

If too much silicon be present, however, and an excessive quantity of slag be formed, it will be found to be rather infusible, and unless care be taken to add the oxides quickly and follow the furnace up—thus rendering the slag more fusible by the extra iron oxide—the furnace bottom is liable to be pulled up. In such cases the author has frequently been able to warn

* Presented at the Joint Meeting of the Iron and Steel Institute and the American Institute of Mining Engineers, London, July, 1906, and here published under a mutual agreement between the Councils of the two Institutes.

a furnace-man that unless he got his slag thinner and less viscous, the bottom would be "up," although no signs of such a bad bottom could be seen at the time. Another disadvantage of too high a percentage of silicon is that the metal is liable to become too hot and froth up through the slag, becoming exposed to the oxidizing atmosphere of the furnace. The metal will then be burnt and carried over into the checkers as oxide (Fe_2O_3), which will be found in a state of fine division in the flues.

Provided the right percentage of silicon is secured in the iron to form a suitable slag naturally, the furnace-man can work the cast much quicker, because of the greater initial heat enabling him to add his oxides faster and so oxidize his metalloids, with an increased yield and a saving of from 1 to 2 hr. per charge.

Where low-silicon pig is used (by low-silicon pig is meant silicon under 1.25 per cent.), free silica or slag may be added to the charge to form a slag or coating to protect the metal. A certain amount of heat is taken up in melting this, and owing to the character of the iron (low-silicon), iron oxide is formed freely. However careful the operator may be, this cannot always be brought, as soon as made, into intimate contact with the free silica or slag added, so that the banks are fluxed and much damage is done to the furnace, with delay for repairs. There is also the probability of the charge breaking out. Of course, in a badly constructed furnace, or when the gas is of poor quality, causing slow melting of the charge, a greater quantity of iron oxide is formed even with a high-silicon pig, and the banks of furnaces will be fluxed, as the ferrous oxide will more readily enter into combination with the free silica from the banks of the furnace than with the silicon in the iron, owing to the low temperature of the bath.

But, given a good furnace, all the essential constituents that go towards the successful working and making of acid open-hearth steel and a low-silicon iron, it will often be found that the charge is boiling before it is quite melted; for the little silicon that is present is quickly oxidized out, and the iron oxide unites with the free silica of the banks and fluxes them badly, principally on the slag line. The damage to the banks is therefore done before the charge is in condition to receive the iron ore or other oxides to oxidize the remaining metal-

loids, or to receive the benefit of the silica in the ore, which might have entered into combination with the iron oxide to form a stable slag and so have protected the banks.

I have always found that, where low-silicon pig is used, a great loss of iron takes place, not only by oxidation through exposure to the flame of the furnace, but also by the loss of iron in the oxides owing to the smaller quantity of oxides which is used. Again, there is never the same vigorous action in the furnace when low-silicon pig is used, owing to the lower initial heat in the charge when molten. A loss of fuel is also attributable to loss of heat by the scanty slag being unable to retain the heat of the metal, as the metal readily chills when unprotected by a good siliceous slag.

The argument is put forward by some iron manufacturers that, with the smaller percentage of silicon, the steelmaker gains, in a corresponding degree, a greater percentage of iron in the pig-iron. This may appear to be so on the surface, but supposing 25 tons of pig-iron be charged in a 40-ton charge, a difference of even 1 per cent. of silicon means 5 cwt. of iron, and far more than this is oxidized and wasted, not to mention the extra time taken in working the cast, and the delay in repairing the furnace banks.

Again, a 40-ton furnace charging cold material will make 3.5 tons of steel per hr., so that if a charge of low-silicon pig takes from 1 to 2 hr. longer, it means that from 3.5 to 7 tons less steel are made, with a consequent rise in the cost of fuel, labor, etc., per ton of steel actually produced.

Regarding the making of a slag artificially, I believe this to be necessary only in the manufacture of high-grade steel, where the time taken to work a cast is not of much moment and the yields are never thought of. In this case an extra quantity of slag would reduce the rapid oxidation, and aid in the production of high-carbon steels. It would also eliminate any tendency of the metal to become "wild" by reducing the amount of active oxide in the slag. For the ordinary grade of steels a large output and a good yield is obtained only by having enough silicon in the iron to form a natural coating—neither scanty nor excessive, but just sufficient to allow of the rapid additions of oxides and oxidation of the metalloids.

My experience with high-silicon and low-silicon pig is that,

when using pig with silicon of 2 per cent. and over, the banks are seldom, if ever, fluxed; but that bad bottoms very often occur if the furnace-man lags behind, and does not add his oxides quickly enough to keep his slag from becoming viscous. When using low-silicon pig (1 per cent. and under) the banks are invariably fluxed, but the bottom of the furnace very seldom comes up. Therefore, in the acid open-hearth process, a middle course must be steered by using an iron with the silicon neither very high nor yet very low, and my experience is that an iron containing from 1.25 to 2 per cent. of silicon is an ideal one for the acid open-hearth melter.

There is no doubt that the up-to-date iron manufacturer is handicapped when making high-silicon iron (above 1.25 per cent.) and the acid-steel maker is also handicapped when using iron under 1.25 per cent. To bring the steel maker into line with the iron maker, I suggest that, in furnaces making acid steel with low-silicon iron, the acid bottoms now used should be replaced by basic bottoms, and the low-silicon hematite iron worked on the basic bottom.

This could not be called a basic process, the essential aim and feature of the basic process (dephosphorization) being absent, and only enough lime (from 3 to 5 per cent.) need be added to render the slag just sufficiently basic to prevent the banks and bottoms being fluxed. It would be an acid process on a basic bottom, and the quality of the resulting steel would be superior to the average quality made on acid bottoms. The output would also be increased from 15 to 20 per cent., as so much more steel-scrap could then be used in the charge.

While numerous papers have been read at various times on the effect of low and high silicon, etc., in the retarding or otherwise of the operation of refining iron by the open-hearth process, a very important constituent in the iron—viz., carbon in the graphitic form—does not seem to have met with the attention which it really deserves.

Mr. Talbot has given the metallurgical world one of the most interesting processes of recent years, and one in which the various reactions can better be perceived and studied than in the ordinary process of first melting and then decarburizing, etc., by slow degrees.

In a 160-ton furnace where hematite iron is used, silicon—

contrary to one's expectation—is not a trouble to the same extent as graphite. The fluxing effect of the silicon on the banks of the furnace is easily neutralized by the addition of lime, provided the approximate percentage of silicon in the iron be known; and although no mixer be used and the iron be obtained from one blast-furnace, the silicon does not vary very much, although the graphite does, and it is this graphite which retards the process of steel-making—more so even than phosphorus or high silicon would.

Generally, however, a high percentage of silicon in the iron is accompanied by a high percentage of graphite, and therefore high silicon is a disadvantage only because it is accompanied by a separation of the carbon in the graphitic form.

When a charge of iron containing a high percentage of graphite is worked, the whole bath in the furnace is covered with a layer of "kish," and sand-shovels can be put into the furnace and the carbon actually ladled off the surface of the bath. When the iron is of this nature, the whole bath lies dormant until the carbon is partly burnt off and partly converted into the combined state. As soon as this takes place the bath becomes active again. While the bath is lying inactive it means so much time lost and greater consumption of fuel, etc., as the furnace charge is practically at a standstill, sometimes as long as two hours. The addition of oxides or even a vigorous mechanical agitation of the bath does not in the least affect this state of affairs, and it is necessary to wait until the graphite is partly burnt off and partly converted into the combined form. When the percentage of graphite is low none of the above disadvantages are met with, as the metalloids in the iron and the oxides in the bath gently react without cessation, and no delay takes place. Further, whereas the average time taken in pouring a ladle of low-graphite iron into the furnace is only about 30 min., it takes from 1.5 to 2 hr. to pour in an equal quantity of high-graphite iron, owing to the very violent reactions which take place. The operation of pouring iron into the highly oxidized bath may be steadily proceeded with in the case of iron containing carbon in the combined form and low graphitic contents, as a steady reaction between oxides and metalloids takes place throughout the whole operation and until the carbon reaches the required percentage.

When the carbon in the iron is high in graphite, no reaction takes place for some time, so that only from 3 to 5 tons are poured in at a time, because when the reaction does take place, from 10 to 30 min. afterwards, it is so sudden and violent that slag, and oft-times metal, is thrown out of the doors, and the reaction is so great that the flame sometimes reaches across the stage and up to the roof of the shop, causing great pressure in the furnace. Of course, when this happens, gas and air are shut off until the reaction subsides. A few more tons of iron are then poured in, and usually another long wait ensues until the oxides and metalloids react. It is this waiting, interrupting the continuity of the process, lowering the output, and causing wear and tear of the furnace and a higher consumption of fuel, etc., which renders the presence of graphite objectionable.

Usually after emptying the ladle of high-graphite iron, the longest spell of inactivity takes place, due most likely to the lower temperature of the bath, the more feeble oxidizing power of the slag, and the presence of a greater quantity of graphite, which, floating on the top of the molten iron, is unavoidably poured in with the last lot of iron in the ladle. This spell of inactivity may last as long as from 1 to 1.5 hr. before the bath begins to boil. All this tends to show that free carbon in iron has a very marked effect in retarding the process, although far less attention has been paid to the effects of graphite than their importance demands.

I have found that when iron with a high percentage of combined carbon was supplied, instead of highly graphitic iron, the output was immediately increased 25 per cent., and the wear and tear on the furnace was reduced 100 per cent. These figures speak for themselves. The intermediate process between the foregoing "all molten" and the ordinary process of charging all cold materials was used for a few years, but it has been discontinued, as the desired advantage was not obtained, because the iron had to be brought direct from the blast-furnace (there being no mixer), and it was therefore impossible to get it just at the proper time to suit the steel furnaces. At the acid open-hearth furnaces, 28 tons of cold material were charged, and when this was about melted from 10 to 12 tons of molten iron were added. If the percentage of silicon was not too low, and

the iron not too high in graphite, there was usually gained, on an average, an hour per charge over the ordinary process of cold charging; but when the iron was high in graphite, time was lost in decarburizing, and instead of gaining an hour, an hour would be lost over the ordinary process. The foregoing applies to the effect of graphite when using molten iron. But does not the same condition of affairs exist in the ordinary process of charging cold material? When using pig-iron containing a high percentage of silicon, is not the longer time taken in working such a charge—generally attributed to the high percentage of silicon—really due to the high percentage of graphite present? Why do some charges, using equal quantities of iron, with the same percentages of silicon, and practically the same percentages of total carbon, take so much longer to decarburize than others, under similar working conditions of heat, etc.? During the period of melting, the percentage of carbon when in the combined form is greatly reduced by being partly oxidized in the oxidizing atmosphere in the furnace; but when carbon is present mostly in the graphitic state, this reduction does not take place, as the carbon is being converted into the combined form, so that when the charge is melted a greater percentage of carbon is present to be decarburized by the oxides added. When using high-graphite iron I find that less than ten per cent. of the estimated carbon contents are eliminated during the melting period. This differs greatly from the 30 or 45 per cent. given by Harbord and Campbell in their books.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Constitution of Iron-Carbon Alloys.*

BY ALBERT SAUVEUR, CAMBRIDGE, MASS.

(London Meeting, July, 1906.)

IT is not without some hesitation, and even misgiving, that I venture into a discussion of the now classical Roberts-Austen Roozeboom diagram, lest I too fail, like so many other writers, in giving a satisfactory and logical explanation of these interesting curves.

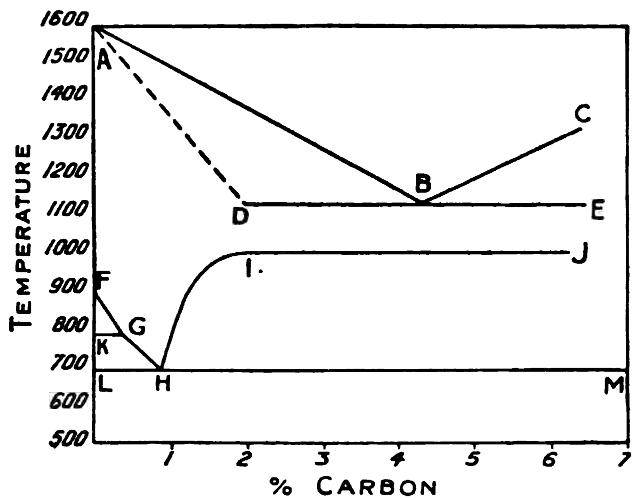

FIG. 1.—ROOZEBOOM'S ORIGINAL DIAGRAM (REPRODUCED).

Roozeboom's original diagram is reproduced in Fig. 1. The generally accepted meaning of the various curves has been so often described before this Institute that it will suffice to recall it briefly before passing to my own interpretation of the changes involved.

* Presented at the Joint Meeting of the Iron and Steel Institute and the American Institute of Mining Engineers, London, July, 1906, and here published under a mutual agreement between the Councils of the two Institutes.

In Fig. 2, I have divided the diagram into three parts by dotted lines, and I have designated them I., II. and III., respectively.

In part I. is shown the fusibility-curve of iron-carbon alloys containing from zero to 2 per cent. of carbon, and seeing that it consists of a straight line, or at least a smooth curve, drawn between the melting-point of pure iron and that of iron containing 2 per cent. of carbon, it may at once be inferred (from a knowledge of the meaning of such curves in general) that alloys of iron and carbon up to 2 per cent. of carbon form a solid solution when they pass from the liquid to the solid state, which means, as Professor Howe has well stated, that the merg-

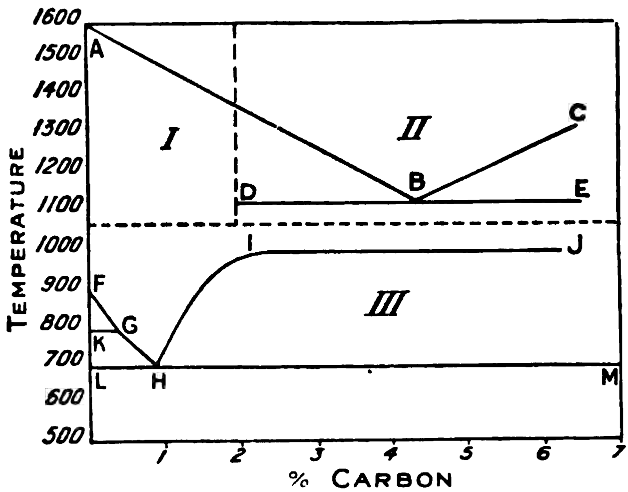

FIG. 2.—SAUVEUR'S MODIFICATION OF ROOZEBOOM'S DIAGRAM.

ing between the carbon and the iron remains complete and in indefinite proportions—the essential characteristics of solution. Were we, however, to follow this analogy further we could logically infer that the two constituents of this solid solution must be: (1) iron free from carbon, and (2) iron containing 2 per cent. of carbon, and that the latter constituent is dissolved in the former. If this be so, we would at once ask what is the nature of that constituent which contains 2 per cent. of carbon. Is it a carbide of iron which is thus dissolved in the iron? I am well aware that this is not the generally accepted conception of the nature of the solid solution, it being assumed that it is the carbon itself which is dissolved and not a carbide

of iron. It should be borne in mind, however, that this view is somewhat opposed by the analogy offered by alloys in general, and while in further discussing the diagram I shall refer to the solid solution as a solution of carbon in iron, it will be with the reservation that, to my mind, it has never been shown conclusively that it was carbon rather than a carbide which was dissolved by the iron, and that the latter inference may be the more logical one.

It may be recalled also that the position of the point D (Fig. 1) has not been positively ascertained, and this should be remembered when we assume that 2 per cent. represents the maximum amount of carbon in the solid solution.

Furthermore, since it is generally accepted that iron at a high temperature exists in a certain allotropic condition known as gamma iron, we must infer that this solid solution is a solution of carbon (or of a carbide) in gamma iron.

It is for this solid solution that Osmond has proposed the name of "austenite," and there should not be any room for misunderstanding or confusion regarding the meaning of that term. This austenite remains stable until the lower critical points, soon to be described, are reached. Let it also be borne in mind that the proportion of carbon in austenite necessarily increases gradually from zero to 2 per cent., according to the carbon-content of the alloy, and that it should be expected that the properties of austenite will likewise vary.

Passing now to the zone marked II., we have here the fusibility curve of iron-carbon alloys containing more than 2 per cent. of carbon. The diagram at once suggests the typical fusibility curve of alloys forming neither solid solutions nor definite compounds, and, therefore, forming a eutectic alloy. Its meaning is clear. Two constituents form upon solidification: (1) graphite, and (2) a solid solution of carbon in iron containing 2 per cent. of carbon, which, for simplicity of speech, may be designated "2-per cent. austenite," while the meeting point of the two curves indicates the formation of a eutectic alloy (graphite + 2 per cent. austenite eutectic), which contains about 4.3 per cent. of carbon. The constitution, after solidification of these highly carburized alloys, can then be readily inferred. If the metal contains from 2 to 4.3 per cent. of carbon, it will be made up of (1) what may be termed

"excess" austenite, and (2) graphite-austenite eutectic, the former constituent decreasing in quantity, and the latter increasing as the carbon-content in the alloy increases. If the alloy contains over 4.3 per cent. of carbon, it will consist of (1) excess graphite, and (2) graphite-austenite eutectic, the former increasing and the latter decreasing in quantity with the carbon-content in the alloy.

In Fig. 3, I have attempted to show graphically in the diagram itself the composition of iron-carbon alloys, after solidification, in percentages of the constituents. The scheme adopted has now been used by several writers, and will, I believe, be readily understood. In the lower part of the diagram a similar graphical representation is given of the constituents of fully cooled alloys soon to be described.

From previous knowledge of the laws governing the solidifying of metallic alloys in general, it has thus been found possible to account, in an apparently satisfactory manner, for the constitution of iron-carbon alloys immediately after their solidification, and there is much in the evidence presented, and in the unmistakable character of the curves, to impart confidence that the essential features of these inferences at least rest on sound foundation.

Passing to the zone marked III. in Fig. 2, it is here that my opinion differs from that of most previous writers regarding the meanings to be ascribed to the curves in this zone. Let us bear in mind that we are now dealing with a solid metal, so that the evolution of heat noted on cooling is no longer connected with the phenomenon of solidification. There is no further change of state, and these evolutions, which indicate a change of internal energy, must apparently be ascribed either to the formation of chemical compounds or to some allotropic changes. It is well to remember that after the alloy has solidified, and whatever its carbon-content, it can contain only two constituents: (1) graphite, and (2) solid solution or austenite (the eutectic present being merely a mechanical mixture of these two components), and that whatever changes are to take place on further cooling must mean a change in the nature of one or both of these two constituents. If we now examine the curves in this zone III., we see that they again recall strikingly the typical fusibility curves of alloys forming neither solid so-

lutions nor definite compounds, and giving rise, therefore, to a eutectic alloy. That a eutectic-like alloy is formed when a solid iron-carbon alloy cools through a certain critical range, is

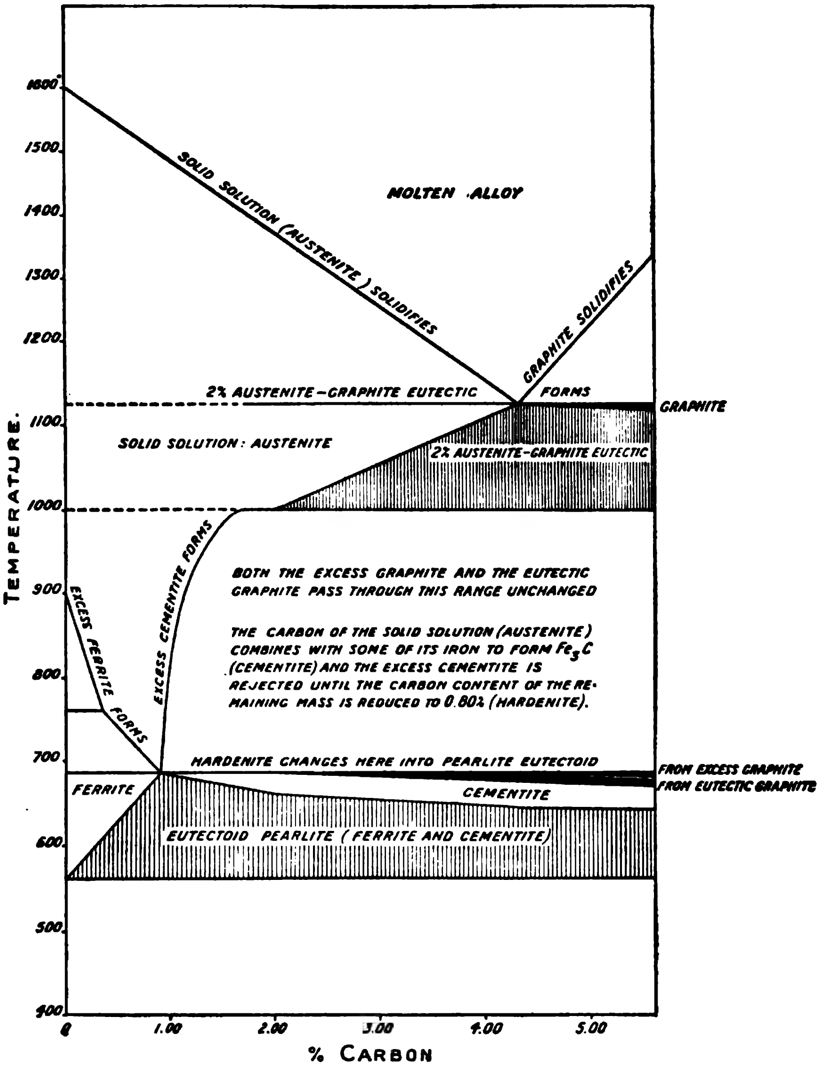

FIG. 3.—COMPOSITION OF IRON-CARBON ALLOYS AFTER SOLIDIFICATION.

known beyond any possible doubt. The two components of that alloy are: (1) iron free from carbon, and (2) a carbide of iron containing 6.67 per cent. carbon, or, to use the metallo-

graphical terms, ferrite and cementite, the alloy itself being called pearlite. It follows from this that the two upper branches—namely, F G H and H I J—must correspond respectively to the formation of the excess ferrite and excess cementite. This leads us to the natural conclusion that the solid solution austenite, which exists at a high temperature, upon further cooling, and at some definite critical temperature, breaks up into ferrite and pearlite, or into cementite and pearlite, according to the carbon-content, or, in other words, that the excess ferrite or the excess cementite falls out of, or segregates from, this solid solution very much like the excess metal falls out of, or crystallizes from, a liquid solution upon reaching the freezing-point of that solution. While there is great analogy between these phenomena, however, there is also a momentous difference in the fact that the formation of pearlite does not imply a change of state. Pearlite is not the alloy of lowest melting-point, which is the meaning of "eutectic." This is why Professor Howe has proposed the very happy term, "eutectoid," for this eutectic-like constituent, and this term should certainly be generally adopted.

That the final constituents of iron-carbon alloys are produced by this breaking up of the solid solution austenite is admitted by all writers, provided the carbon does not exceed 2 per cent.

With a higher carbon-percentage, however—that is to say, when graphite begins to make its appearance on solidifying—it has generally been contended that this graphite plays a part in the further transformation of the alloy. It has been argued that when the line I J (Fig. 2) is reached, cementite is produced not only from the breaking up of the austenite, but also from the graphite actually combining with some of the iron of the austenite to form the carbide Fe_3C. According to these views there is no room for graphite below that line. When graphite is found in an iron-carbon alloy it is assumed that it is due to "lag," by which is meant that because of molecular inertia and the absence of favorable conditions, such as slow cooling, etc., graphite has been prevented from being converted into cementite. According to this view it is held that all cast-irons, free from silicon and other disturbing elements, must normally be white—that is to say, free from graphitic carbon. When they are gray—that is, when they contain

graphitic carbon—their constitution is, so to speak, abnormal, the metal having failed to assume a stable condition.

It seems to me that a careful study of the curves, and still more of the structure of samples after suitable treatments, utterly fails to support this contention, and, indeed, that it points to exactly the opposite conclusion—namely, that the graphite which forms during solidification plays no part in the further transformation of the alloys, and that it merely acts as an inert substance, passing through the critical range unaffected. The formation of graphite in the absence of impurities depends solely upon (1) the total amount of carbon in the alloy, and (2) the rate of cooling through the solidification range. Once formed, I believe that this graphite cannot be made to combine with iron. An alloy containing more than 2 per cent. carbon consists, after solidification, as has been shown, of a mass of solid solution containing many particles or grains of graphite distributed through it, which, for the purpose of illustration, may be compared to a molten mass of some metallic alloy mixed, let us say, with pebbles. Upon cooling and solidifying, the expected changes will take place in the alloy proper, but the pebbles will take no part in it.

In accordance with this conception, I have given in the appendix, and indicated graphically in Fig. 3, what should be the theoretical composition of iron-carbon alloys in percentages ot the constituents, and after slow cooling from the melting-point, and I think that it will be found to agree closely with the structure observed in various grades of steel and cast-iron free from impurities (and especially from silicon and sulphur) and allowed to cool slowly from the molten condition. To ascribe an active part to the graphite in the changes occurring at the critical points is further opposed by our knowledge of the nature and behavior of graphite, for it is well known that once formed no kind of heat treatment has ever resulted in producing any change in its nature.

Let us look a little more closely into the evidences brought forward in support of the contention that the graphite formed during solidification combines on further cooling and at a certain definite temperature with some of the iron to form the carbide Fe_3C.

So far as I am aware this assumption rests chiefly, (1) upon

the presence of the curve I J in the diagram (see Fig. 2), and (2) upon the application of the phase rule to iron-carbon alloys. These may be considered in the order given.

I. *Evidences Based upon the Presence of the Curve I J* (Fig. 2).—While there is very good reason to suppose that the line I J indicates the formation of cementite in the cooling alloy, its existence does not even remotely suggest that this cementite is produced by the combination of graphite with iron. Indeed, it seems to me that all indications point strongly the other way, notwithstanding Roozeboom's opinion that the line I J "can have no other meaning than that at 1,000° there is in the normal state of stable equilibrium an abrupt transformation of the graphite into carbide (cementite)." [1]

Let it be considered that the curve I J is the continuation of the curve H I, and that the intervention of graphite is not needed to explain the meaning of H I. We know that the curve H I indicates the formation of cementite from the solid solution austenite, and it may well be asked what is the justification for abruptly and profoundly modifying the meaning of that curve the moment the carbon-content exceeds 2 per cent., or, in other words, as soon as graphite appears on solidification. It is illogical to ascribe a certain meaning to the portion H I of the curve H I J, and another meaning to the portion I J. How can this be defended? Is there not, on the contrary, every reason to suppose that the meaning of the portion I J is identical with that of H I—namely, that it indicates the segregation of cementite from the solid solution austenite, a phenomenon in which the graphite which happens to be present in highly carburized alloys plays no part? To sum up, it seems to me that the presence of the line I J in the diagram, instead of indicating an active intervention of the graphite, suggests strongly, by analogy, that, like the portion H I of the same curve, it indicates the formation of excess cementite within the austenite.

II. *Evidences Based on the Phase Rule.*—We are told that according to the phase rule only two phases can exist in a state of stable equilibrium in iron-carbon alloys, and that, therefore, if graphite be present, besides ferrite and cementite (pearlite

[1] Iron and Steel from the Point of View of the "Phase Doctrine," *Journal of the Iron and Steel Institute*, vol. lviii., No. II., p.315 (1900).

not being a phase, but merely a mechanical mixture of the two phases, ferrite and cementite), it must be due to "lag"; that is, because the conditions prevailing during the cooling were not favorable to the production of stable equilibrium. According to this view the graphite which forms normally during solidification must disappear on further cooling—i.e., must be converted into cementite by combination with some iron, when passing through the curve I J (Fig. 2).

When iron-carbon alloys solidify they must of course do so in accordance with the phase rule, and after solidification can only contain two phases—namely, graphite and austenite; but once solidified they are converted into a mechanical mixture of these two constituents, and their further transformation can no longer be governed by the phase rule, for that rule is not applicable to mechanical mixtures as such.

To be sure, since one of the constituents of that mixture happens to be a solid solution the further transformations of that constituent, of course, should take place according to the phase rule, and it should not, after final cooling, contain more than two phases; but the alloy as a whole, being a mechanical mixture, is no longer under that rule, so that finally we should have, in a state of stable equilibrium, (1) graphite formed on solidifying, and which remains inert during further cooling, and (2) ferrite and cementite from the transformation of the solid solution, and *in accordance with the phase rule.*

Here, again, I would compare the iron-carbon alloy after solidification to a molten alloy containing pebbles. While the further transformation of the molten alloy itself must take place in accordance with the phase rule, the pebbles will take no part in it, and will be found in the solidified mass.

Having reviewed the arguments advanced in favor of the transformations of graphite into cementite, I shall briefly indicate the evidence supporting the view brought forward in this paper, that of the non-intervention of graphite in any change taking place below solidification.

1. The existence of the curve H I J (Fig. 2), instead of suggesting a transformation of the graphite along the portion I J, strongly suggests that, by analogy, I J must mean, like H I, the rejection of excess cementite from the solid solution (austenite).

2. The well-known behavior of graphite, which resists transformation by any known heat-treatment short of melting, is opposed to the theory.

3. The results of a few experiments which will now be briefly described appear to show conclusively that Roozeboom's theory is untenable.

Some electrolytic iron, produced by Professor Charles F. Burgess of the University of Wisconsin, and kindly supplied by him, was melted in a graphite crucible brasqued with magnesia, together with an excess of sugar charcoal, in a gas crucible furnace.

The composition of the electrolytic iron was as follows:

	Analysis by Professor Burgess. Per Cent.	Author's Analysis. Per Cent.
Carbon,	......	none
Silicon,	none	none
Phosphorus,	0.018	0.013
Sulphur,	0.003	trace
Manganese,	......	none

After melting, the crucible and its contents were allowed to cool very slowly in the furnace. It will be noted that these conditions were exceptionally favorable to the production of a pure iron-carbon alloy in a state of stable equilibrium, they being practically free from the disturbing influence of impurities, and the "lag," so far as due to too rapid cooling at least, being minimized. Absence of impurities and extremely slow cooling should at least promote stable equilibrium; that is, those conditions should promote the transformations which theoretically are assumed to take place at the various thermal critical points. Admitting the necessary interference of "lag," notwithstanding our conditions, and magnifying its importance to the utmost, we should certainly still expect, if Roozeboom's theory be true, the resulting alloy to contain relatively little graphite, certainly less than the amount normally formed during solidification. In other words, under the favorable conditions indicated surely some of the graphite should be converted into cementite. If no such conversion whatever takes place, and if it be still maintained that the theory is nevertheless correct, it assumes a purely speculative and unacceptable character. If, on the contrary, the opposite view be true, the amount of

graphite after slow cooling should not be less than the amount formed during the solidification period, and which can be readily calculated (see appendix) from the percentage of total carbon.

It was found that the iron-carbon alloy produced in this experiment contained 4.354 per cent. of total carbon. This amount of carbon should yield, during solidification, 2.40 per cent. of graphite (see appendix), while the analysis of the alloy showed 3.066 per cent. of graphite. Not only did any graphite fail to combine with iron at the critical temperature of 1,000°, but some of the cementite actually broke up into carbon (tem-

FIG. 4.—ELECTROLYTIC IRON MELTED WITH EXCESS CARBON AND ALLOWED TO SOLIDIFY AND COOLED VERY SLOWLY. Magnified 100 Diameters.

per carbon) and iron during the very slow cooling from this temperature. It will be readily seen that the conditions were such as to cause a certain amount of "malleablyzing."

The amount of silicon in this alloy was found to be 0.028 per cent.

A photomicrograph of this alloy is shown in Fig. 4.

Let us emphasize the meaning of the formation of this large amount of graphite during solidification in the practical absence of silicon and the retention of that graphite in its entirety during slow cooling, and let us oppose this result to such assertions as that of Ledebur, that in order to produce graphite

during solidification " a second element beside carbon must be present";[2] as that of Roozeboom, that the curve I J (Fig. 2) can have no other meaning than that of the disappearance of graphite,[3] and as that of Howe, that graphite in highly carburized iron free from silicon can only be present by " lag."[4]

While in view of the conclusive nature of the results of the experiment just recorded it did not seem necessary to carry the argument further, other experiments, however, were conducted with a view of bringing about this alleged combination of the graphite, but in every case it was found impossible to reduce the amount of graphite formed during solidification.

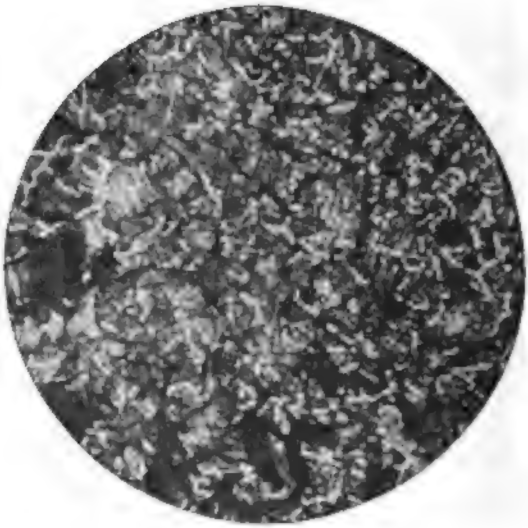

FIG. 5.—SAME ALLOY AS THAT SHOWN IN FIG. 4, BUT REHEATED TO 1,000° C. FOR FIVE HOURS AND VERY SLOWLY COOLED. Magnified 100 Diameters.

It will suffice to describe here two of the most significant of these additional tests.

A piece of the iron-carbon alloy produced in the first experiment was reheated to 1,000° C. (the temperature indicated by I J, Fig. 2), and kept at that temperature for 5 hr. According to the Roozeboom theory we might reasonably expect that some, if only a very little, of the graphite would be converted into cementite, but the amount of total carbon was found to be 2.87

[2] *Handbuch der Eisenhüttenkunde.*

[3] Iron and Steel from the Point of View of the "Phase Doctrine," *Journal of the Iron and Steel Institute*, vol. liii., No. II., p. 315 (1900).

[4] *Iron, Steel, and Other Alloys*, p. 200.

per cent. and the graphitic carbon 1.928 per cent. The theoretical amount of graphite which should form on solidification with a total carbon-content of 2.87 should be 0.89 per cent. It is seen that instead of additional cementite forming, as Roozeboom's theory would have it, a large amount of that constituent was decomposed and 1.038 per cent. temper carbon formed, by keeping the metal at the critical temperature of 1,000° (claimed to be a cementite-forming temperature) and cooling slowly therefrom. The microstructure of this iron is shown in Fig. 5.

Another alloy with excess carbon was melted exactly as in the first experiment, and allowed to solidify slowly in the furnace until its temperature was 1,100° C., when the crucible and contents were quickly transferred to a muffle furnace previously heated to 1,000° C., and maintained at that temperature for five hours. More favorable conditions for the disappearance of graphite, according to Roozeboom's theory, cannot readily be conceived, but it was found that the alloy contained 3.63 per cent. of total carbon and 2.174 per cent. of graphitic carbon, while the amount of graphite which should form theoretically during solidification is 1.63 per cent. (see appendix). Here again, therefore, the graphitic carbon failed to combine with iron, while a considerable amount of temper carbon was produced. The structure of this alloy is shown in Fig. 6. It was found to contain 0.031 per cent. silicon. These results are given in Table I.:

TABLE I.—*Results of Heat-Treatment of Alloys Having Excess Carbon.*

Treatment.	Composition.	Theoretical Quantity of Graphite Formed During Solidification.	Temper Carbon Formed at and Below 1,000° C.
	Per Cent.	Per Cent.	Per Cent.
[a]1. Electrolytic iron, melted with excess carbon and very slowly cooled.	Total carbon........4.354 Graphitic carbon..3.066 Combined carbon..1.288	2.40	0.666
[a]2. Same as No. 1, but reheated to 1,000° C. for 5 hours and slowly cooled	Total carbon........2.870 Graphitic carbon..1.928 Combined carbon..0.942	0.89	1.038
[a]3. Electrolytic iron, melted with excess carbon, allowed to solidify slowly, kept 5 hours at 1,000° C., and cooled slowly.	Total carbon........3.630 Graphitic carbon..2.174 Combined carbon..1.456	1.63	0.544

[a] These carbon determinations were made by Booth, Garrett and Blair, of Philadelphia.

These repeated failures to induce any of the graphite to combine with iron under the most favorable conditions that could be devised, appear to be conclusive evidences that the graphite which forms during the slow solidification of highly carburized iron takes no part in any further transformation, and is to be found in the cooled alloy, not by "lag," but by right.

It is hardly necessary here to explain why commercial cast-irons are produced which contain a great deal more graphite than the theoretical amount, and indeed in which cementite

FIG. 6.—ELECTROLYTIC IRON MELTED WITH EXCESS CARBON, ALLOWED TO SOLIDIFY SLOWLY, KEPT FIVE HOURS AT 1,000° C., AND SLOWLY COOLED. Magnified 100 Diameters.

may be altogether absent, while others contain much less graphite than the theoretical amount, and may even be free from that constituent. The former variety owe their constitution chiefly to the presence of silicon, which, during solidification, promotes the formation of an excess graphite above the theoretical amount, while the latter variety shows a deficit, or even a complete absence, of graphite, chiefly because of too rapid a solidification, and frequently also because of the presence of sulphur, or of some other interfering element opposing the formation of graphite. In order to obtain the theoretical

amount of graphite, two conditions are essential: (1) very slow cooling during solidification, and (2) absence of disturbing foreign elements, and these conditions are not realized in commercial cast-iron. If the silicon, sulphur and other impurities be removed from cast-iron, and the alloy be then allowed to solidify very slowly, the theoretical amount of graphite will be produced and retained whether the iron was originally gray, mottled or white.

Before bringing this argument to a close, a few words should be said regarding the production of malleable cast-iron castings, and which, as is well known, results from long annealing of white cast-iron castings at a temperature generally not far from 1,000° C., or precisely the temperature indicated by the curve I J (Fig. 2), where formation of cementite, and not of graphite, should be induced according to Roozeboom's theory. Strangely enough, however, the advocates of that theory seem to find in the results of this operation an argument in support of their view. When white cast-iron is heated to 1,000° C., why should any graphitic or "temper" carbon be formed? Is it not opposed to Roozeboom's theory? Is not white cast-iron at 1,000° C. in a state of stable equilibrium, seeing that all its carbon is combined, as it should be, according to that theory? How, then, can this spontaneous transformation of a stable into an unstable equilibrium (formation of graphitic carbon) be explained?

On the contrary, if the view be accepted that graphite should be normally formed and retained on slow cooling, we are led to look upon white cast-iron as being in a state of unstable equilibrium, and it can readily be understood how, by a single reheating, even much below the melting-point, a certain return to that state must take place, which means the formation of a certain amount of graphitic, or, as it is often called, "temper" carbon. This behavior of white cast-iron is very similar to that of hardened steel subjected to tempering. Both white cast-iron and hardened steel are in an unstable condition, the former because of too rapid cooling through the solidification period, the latter because of too rapid cooling through the critical range (700° C., or thereabout). Both metals have a latent tendency to assume a more stable condition, which means the formation of cement carbon in hardened steel and the for-

mation of graphitic carbon in white cast-iron, and both metals will show a partial return, at least, to a more stable condition if they be heated to a temperature which may be considerably below the critical point through which the metal was cooled too quickly—namely, below 700° C. for hardened steel, and below the solidification temperature in the case of white cast-iron. These facts are summarized in Table II.:

TABLE II.—*Characteristics of Hardened Steel and White Cast-Iron.*

	Unstable because of Too Rapid Cooling through.	Result of Too Rapid Cooling.	Restored Partially or Wholly to Stable Condition.	Result of Reheating.
Hardened steel.	Critical range.	Formation of cement carbon prevented.	By reheating below critical range.	Formation of cement carbon.
White cast-iron.	Solidification range.	Formation of graphitic carbon prevented.	By reheating below solidification range.	Formation of graphite or "temper" carbon.

The weight of evidence appears to me strongly to point to white cast-iron being in an unstable condition, the formation of graphite having been prevented through too sudden cooling or because of the presence of disturbing elements. The stable alloy should contain the normal amount of graphite formed on solidification, and reheating to a relatively low temperature will permit a partial or complete return of the metal to its stable condition; hence the possible conversion of white cast-iron into malleable, graphitic iron by annealing.

AUSTENITE, MARTENSITE, TROOSTITE, AND PEARLITE.

In Fig. 7, I have drawn, on a large scale, the thermal curves of iron-carbon alloys resulting from the evolutions of heat which take place spontaneously long after the metal has solidified. This diagram is an attempt to give a graphic representation of the following well-known and generally accepted facts:

(1) The point Ar3 in carbonless iron and in low-carbon alloys corresponds to the passage of the iron from the allotropic condition, gamma, to the allotropic condition, beta; and also to the separation of some excess ferrite, which must necessarily be beta ferrite.

(2) The point Ar2 in carbonless and low-carbon alloys corresponds to the passage of the iron from the allotropic condition, beta, to the allotropic condition, alpha, and probably to the separation of an additional amount of excess ferrite, which must necessarily be alpha ferrite.

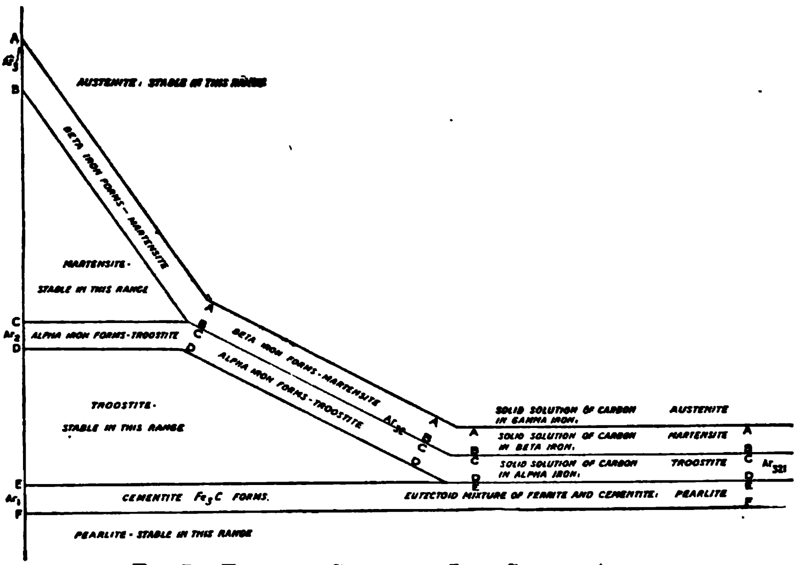

FIG. 7.—THERMAL CURVES OF IRON-CARBON ALLOYS.

(3) The point Ar1 in low-, medium- and high-carbon alloys is due to the formation of the carbide Fe_3C, or cementite.

(4) The point Ar3,2 of medium high-carbon alloys implies that the Ar3 and Ar2 changes just described occur at, or nearly at, the same temperature, the gamma iron passing to beta iron and immediately after to alpha iron, while the excess ferrite separates.

(5) The point Ar3,2,1 of high-carbon steel implies that the changes Ar3, Ar2, and Ar1 now occur at, or nearly at, the same temperature, the gamma iron passing to beta, then imme-

diately to alpha, while the carbide Fe_3C forms, which compound must necessarily be a carbide of alpha iron.

Before discussing at greater length the meaning of these curves, I desire to state emphatically that I am not propounding here any new theory, especially as to the nature of troostite, but merely inquiring into the meaning of the changes taking place at the thermal critical points.

The inferences to be drawn from this diagram may possibly be made clearer by a series of questions which it suggests.

Is it not evident that the two allotropic changes which take place at Ar3,2 do not occur simultaneously, but successively? Must not the gamma iron first pass to the beta state before assuming the alpha condition? This is clearly indicated in the diagram.

Is it not likewise evident that the three changes which occur at Ar3,2,1 do not take place simultaneously, but successively? Does not this critical point involve three distinct and successive transformations: (1) the passage of gamma iron to beta iron, (2) the passage of beta iron to alpha iron, and (3) the formation of the carbide Fe_3C? This interpretation of the single point Ar3,2,1 is also clearly shown graphically in the diagram.

After cooling through AB—that is, through Ar3 or through the upper zone of Ar3,2 or of Ar3,2,1—does not the iron-carbon alloy consist of a solid solution of carbon in beta iron (mixed, in the case of low-carbon steel, with some free beta ferrite), and does not this condition remain stable, through the range BC, which range is, of course, reduced to a line in the case of the points Ar3,2 and Ar3,2,1?

Is not martensite the proper name for this solid solution of carbon in beta iron, and which must be necessarily formed at some temperature, whatever the carbon-content of the alloy, and which is also the first transformation of austenite, that is, of the solid solution of carbon in gamma iron? Is not this in perfect agreement with Osmond's description of these two constituents, and should there remain any more doubt or confusion as to their nature? Martensite is harder than austenite simply because of the fact that the beta iron which it contains is harder than gamma iron. Are not then austenite and martensite two distinct and well-defined constituents? It is, of course, well

known that in the ordinary quenching we do not usually prevent the passage of austenite into martensite—that is, of gamma into beta iron—from which it follows that martensite, and not austenite, is the ordinary constituent of hardened steel, and it is also well known that the further transformation of martensite is greatly retarded by the presence of carbon, so that, in a high-carbon steel, we are able to retain martensite much more readily than with a lower carbon-content. By the very sudden quenching of high-carbon steel it is possible to retain, as Osmond has shown, about half of the alloy in the austenite condition, the other half assuming the martensite state.

Passing now to the range CD, that is, to the point Ar2, or to the lower zone of Ar3,2, or the middle zone of Ar3,2,1, does not the iron change here from the beta to the alpha condition, and does not the alloy now consist of a solid solution of carbon in alpha iron? If this be not correct we must revise our conception of the meaning of the point Ar2. And does not this solid solution of carbon in alpha iron remain stable and unchanged through the range DE, which, of course, in high carbon steel is reduced to a single line, and is not this solid solution of carbon in alpha iron the illusive and much maligned constituent troostite? Is it not logical to infer that it is troostite? Does it not correspond to the first transformation of martensite or hardenite before its final conversion into pearlite while passing through the range EF, that is, through Ar1 or through the lower zone of Ar3,2,1? Does not this conception agree with the generally accepted view that troostite is a transition constituent between martensite and pearlite? Is not such conception of the nature of troostite in agreement with our knowledge of the conditions required for its formation and with its properties, and, indeed, is it opposed by any evidences so far brought forward? To produce troostite we must cool the alloy through the critical range slowly enough to allow its formation and rapidly enough to prevent its further transformation into pearlite, or we may obtain it by cooling suddenly from the lower zone of the critical range—that is, from the temperature DE, where troostite has been formed and is for the time being a stable constituent. Here, again, it should be borne in mind that it is not generally possible to retain all the alloy in the condition of

TABLE III.—*Structural Compo-*

Per Cent. of Carbon in Alloy.	Structural Composition After Solidification.										
	Proximate Composition.			Ultimate Composition.						Proximate	
	Eutectic (A′ + G′). E.	Excess Austenite. A.	Excess Graphite. G.	Eutectic Austenite. A′.	Excess Austenite. A.	Eutectic Graphite. G′.	Excess Graphite. G.	Total Austenite. A + A′.	Total Graphite. G + G′.	Pearlite (F′ + C′). P.	Excess Ferrite. F.
0.10	...	100	...	...	100	...	...	100	...	12.50	87.50
0.20	...	100	...	...	100	...	...	100	...	25.00	75.00
0.30	...	100	...	...	100	...	...	100	...	37.50	62.50
0.40	...	100	...	...	100	...	...	100	...	50.00	50.00
0.50	...	100	...	...	100	...	...	100	...	62.50	37.50
0.60	...	100	...	...	100	...	...	100	...	75.00	25.00
0.70	...	100	...	...	100	...	...	100	...	87.50	12.50
0.80	...	100	...	...	100	...	...	100	...	100	...
0.90	...	100	...	...	100	...	...	100	...	98.30	...
1.00	...	100	...	...	100	...	...	100	...	96.59	...
1.10	...	100	...	...	100	...	...	100	...	94.89	...
1.20	...	100	...	...	100	...	...	100	...	93.19	...
1.30	...	100	...	...	100	...	...	100	...	91.48	...
1.40	...	100	...	...	100	...	...	100	...	89.78	...
1.50	...	100	...	...	100	...	...	100	...	88.07	...
1.60	...	100	...	...	100	...	...	100	...	86.37	...
1.70	...	100	...	...	100	...	...	100	...	84.67	...
1.80	...	100	...	...	100	...	...	100	...	82.96	...
1.90	...	100	...	...	100	...	...	100	...	81.26	...
2.00	...	100	...	...	100	...	...	100	...	79.56	...
2.10	4.35	95.65	...	4.25	95.65	0.10	...	99.90	0.10	79.48	...
2.20	8.70	91.30	...	8.50	91.30	0.20	...	99.80	0.20	79.40	...
2.30	13.04	86.96	...	12.73	86.96	0.31	...	99.69	0.31	79.31	...
2.40	17.39	82.61	...	16.98	82.61	0.41	...	99.59	0.41	79.23	...
2.50	21.74	78.26	...	21.23	78.26	0.51	...	99.49	0.51	79.15	...
2.60	26.09	73.91	...	25.48	73.91	0.61	...	99.39	0.61	79.07	...
2.70	30.43	69.57	...	29.72	69.57	0.71	...	99.29	0.71	78.99	...
2.80	34.78	65.22	...	33.96	65.22	0.82	...	99.18	0.82	78.90	...
2.90	39.13	60.87	...	38.21	60.87	0.92	...	99.08	0.92	78.83	...
3.00	43.48	56.52	...	42.46	56.52	1.02	...	98.98	1.02	78.75	...
3.10	47.83	52.17	...	46.71	52.17	1.12	...	98.88	1.12	78.67	...
3.20	52.17	47.83	...	50.95	47.83	1.22	...	98.78	1.22	78.59	...
3.30	56.52	43.48	...	55.20	43.48	1.32	...	98.68	1.32	78.51	...
3.40	60.87	39.13	...	59.45	39.13	1.42	...	98.58	1.42	78.43	...
3.50	65.22	34.78	...	63.70	34.78	1.52	...	98.48	1.52	78.35	...
3.60	69.57	30.43	...	67.94	30.43	1.63	...	98.37	1.63	78.26	...
3.70	73.91	26.09	...	72.18	26.09	1.73	...	98.27	1.73	78.18	...
3.80	78.26	21.74	...	76.43	21.74	1.83	...	98.17	1.83	78.10	...
3.90	82.61	17.49	...	80.67	17.39	1.94	...	98.06	1.94	78.02	...
4.00	86.96	13.04	...	84.92	13.04	2.04	...	97.96	2.04	77.94	...
4.10	91.31	8.69	...	89.17	8.69	2.14	...	97.86	2.14	77.86	...
4.20	95.66	4.04	...	93.41	4.34	2.25	...	97.75	2.25	77.78	...
4.30	100.0	...	...	97.65	...	2.35	...	97.65	2.35	77.69	...
4.40	99.90	...	0.10	97.55	...	2.35	0.10	97.55	2.45	77.63	...
4.50	99.80	...	0.20	97.46	...	2.34	0.20	97.46	2.54	77.53	...
4.60	99.69	...	0.31	97.35	...	2.34	0.31	97.35	2.65	77.45	...
4.70	99.59	...	0.41	97.25	...	2.34	0.41	97.25	2.75	77.37	...
4.80	99.48	...	0.52	97.14	...	2.34	0.52	97.14	2.86	77.28	...
4.90	99.38	...	0.62	97.05	...	2.33	0.62	97.05	2.95	77.21	...
5.00	99.27	...	0.73	96.94	...	2.33	0.73	96.94	3.06	77.12	...

sition of Various Iron-Carbon Alloys.

Structural Composition After Slow Cooling.

Composition.		Ultimate Composition.						Total Ferrite. F + F'.	Total Cementite. C + C'.	Total Graphite. G + G'.
Excess Cementite. C.	Total Graphite. G + G'.	Eutectoid Ferrite. F'.	Excess Ferrite. F.	Eutectoid Cementite. C'.	Excess Cementite. C.	Eutectic Graphite. G'.	Excess Graphite. G.			
...	...	11.00	87.50	1.50	...	...	...	98.50	1.50	...
...	...	22.00	75.00	3.00	...	...	...	97.00	3.00	...
...	...	33.00	62.50	4.50	...	...	...	95.50	4.50	...
...	...	44.00	50.00	6.00	...	...	...	94.00	6.00	...
...	...	55.00	37.50	7.50	...	...	...	92.50	7.50	...
...	...	66.00	25.00	9.00	...	...	...	91.00	9.00	...
...	...	77.00	12.50	10.50	...	...	...	89.50	10.50	...
...	...	88.00	...	12.00	...	...	...	88.00	12.00	...
1.70	...	86.50	...	11.80	1.70	...	...	86.50	13.50	...
3.41	...	85.00	...	11.59	3.41	...	...	85.00	15.00	...
5.11	...	83.50	...	11.39	5.11	...	...	83.50	16.50	...
6.81	...	82.00	...	11.19	6.81	...	...	82.00	18.00	...
8.52	...	80.50	...	10.98	8.52	...	...	80.50	19.50	...
10.22	...	79.00	...	10.78	10.22	...	...	79.00	21.00	...
11.93	...	77.50	...	10.57	11.93	...	...	77.50	22.50	...
13.63	...	76.00	...	10.37	13.63	...	...	76.00	24.00	...
15.33	...	74.50	...	10.17	15.33	...	...	74.50	25.50	...
17.04	...	73.00	...	9.96	17.04	...	...	73.00	27.00	...
18.74	...	71.50	...	9.76	18.74	...	...	71.50	28.50	...
20.44	...	70.00	...	9.56	20.44	...	...	70.00	30.00	...
20.42	0.10	69.94	...	9.54	20.42	0.10	...	69.94	29.96	0.10
20.40	0.20	69.87	...	9.53	20.40	0.20	...	69.87	29.93	0.20
20.38	0.31	69.79	...	9.52	20.38	0.31	...	69.79	29.90	0.31
20.36	0.41	69.72	...	9.51	20.36	0.41	...	69.72	29.87	0.41
20.34	0.51	69.65	...	9.50	20.34	0.51	...	69.65	29.84	0.51
20.32	0.61	69.58	...	9.49	20.32	0.61	...	69.58	29.81	0.61
20.30	0.71	69.51	...	9.48	20.30	0.71	...	69.51	29.78	0.71
20.28	0.82	69.43	...	9.47	20.28	0.82	...	69.43	29.75	0.82
20.25	0.92	69.37	...	9.46	20.25	0.92	...	69.37	29.71	0.92
20.23	1.02	69.30	...	9.45	20.23	1.02	...	69.30	29.68	1.02
20.21	1.12	69.23	...	9.44	20.21	1.12	...	69.23	29.65	1.12
20.19	1.22	69.16	...	9.43	20.19	1.22	...	69.16	29.62	1.22
20.17	1.32	69.09	...	9.42	20.17	1.32	...	69.09	29.59	1.32
20.15	1.42	69.02	...	9.41	20.15	1.42	...	69.02	29.56	1.42
20.13	1.52	68.95	...	9.40	20.13	1.52	...	68.95	29.53	1.52
20.11	1.63	68.87	...	9.39	20.11	1.63	...	68.87	29.50	1.63
20.09	1.73	68.80	...	9.38	20.09	1.73	...	68.80	29.47	1.73
20.07	1.83	68.73	...	9.37	20.07	1.83	...	68.73	29.44	1.83
20.04	1.94	68.66	...	9.36	20.04	1.94	...	68.66	29.40	1.94
20.02	2.04	68.59	...	9.35	20.02	2.04	...	68.59	29.87	2.04
20.00	2.14	68.52	...	9.34	20.00	2.14	...	68.52	29.34	2.14
19.97	2.25	68.45	...	9.33	19.97	2.25	...	68.45	29.30	2.25
19.96	2.35	68.37	...	9.32	19.96	2.35	...	68.37	29.28	2.35
19.92	2.45	68.32	...	9.31	19.92	2.35	0.10	68.32	29.23	2.45
19.93	2.54	68.23	...	9.30	19.93	2.34	0.20	68.23	29.23	2.54
19.90	2.65	68.16	...	9.29	19.90	2.34	0.31	68.16	29.19	2.65
19.88	2.75	68.09	...	9.28	19.88	2.34	0.41	68.09	29.16	2.75
19.86	2.86	68.01	...	9.27	19.86	2.34	0.52	68.01	29.13	2.86
19.84	2.95	67.95	...	9.26	19.84	2.33	0.62	67.95	29.10	2.95
19.82	3.06	67.87	...	9.25	19.82	2.33	0.73	67.87	29.07	3.06

troostite, because the formation of these transition forms does not take place simultaneously throughout the same specimen. By properly regulated cooling we shall obtain a mixture of troostite and martensite, while if the cooling be less rapid the result will be a mixture of troostite and pearlite, or, indeed, a mixture of these three constituents, while, of course, in low carbon steel some excess ferrite may also be present.

To sum up the above considerations, microscopical evidences have shown conclusively that four distinct constituents are formed through the cooling of steel—namely, austenite, martensite, troostite and pearlite—and it has also been shown that martensite, and especially troostite, may be regarded as transition constituents in the transformation of austentite into pearlite. Now, on the other hand, if we look into the meaning of the thermal critical points of steel, as illustrated in Fig. 7, we also find that four constituents must necessarily be formed during the cooling of steel, and that these must be respectively (1) solid solution of carbon in gamma iron, (2) solid solution of carbon in beta iron, (3) solid solution of carbon in alpha iron, and (4) the iron-carbide eutectoid, and the conclusion that these four constituents must be those revealed by microscopical examination—that is, respectively austenite, martensite, troostite and pearlite—appears not only reasonable, but, it seems to me, inevitable.

APPENDIX.

Calculations to Obtain the Percentages of the Constituents of Iron-Carbon Alloys.

The percentages of the various constituents which should normally be present in iron-carbon alloys may be readily calculated provided the proportion of total carbon be known.

In these calculations the following notations are used:—

A = Excess Austenite.
A′ = Eutectic Austenite.
G = Excess Graphite.
G′ = Eutectic Graphite.
E = Graphite-Austenite Eutectic (A′+G′).
F = Excess Ferrite.
F′ = Eutectoid Ferrite.
C = Excess Cementite.
C′ = Eutectoid Cementite.
P = Pearlite or Ferrite-Cementite Eutectoid (F′+ C′).
R = Percentage of Carbon in the alloy.

Let us consider (I.) the composition after solidification, and (II.) the composition after slow cooling to atmospheric temperature, or at least below the lower critical point.

I. *Composition after Solidification.*

Three cases are to be considered: (1) the alloy contains less than 2 per cent. of carbon, (2) the alloy contains between 2 and 4.3 per cent. of carbon, and (3) the alloy contains more than 4.3 per cent. of carbon.

1. Alloys which contain less than 2 per cent. of carbon are made up, after solidification, exclusively of the solid solution austenite, $A = 100$ per cent.

2. Alloys containing between 2 and 4.3 per cent. of carbon consist, after solidification, of excess austenite (A), and of a eutectic alloy (E), which in turn is a mechanical mixture of austenite (A′), and graphite (G′).

We have—

(1) $A+E = 100$, and since the excess austenite contains 2

per cent. of carbon and the eutectic 4.3 per cent. of carbon, we must have

$$(2) \qquad \frac{2.00}{100}A + \frac{4.3}{100}E = R$$

in which R represents the known percentage of carbon in the alloy.

The percentage of graphite in the eutectic may likewise be readily obtained. Let A′ and G′ represent, respectively, the amount of austenite and of graphite in the eutectic, then

$$(a) \; A' + G' = 100$$

and

$$(b) \; \frac{2.00}{100} A' + G' = 4.3$$

which gives $G' = 2.35$ for the percentage of graphite in the eutectic.

Let us suppose, for instance, that the alloy contains 3.5 per cent. of carbon. The above calculations will give for the, so to speak, proximate structural composition, immediately after solidification:

	Per Cent.
Excess austenite (A),	34.78
Eutectic (E),	65.22
	100.00

and for its ultimate structural composition—

	Per Cent.
Excess austenite (A),	34.78
Eutectic austenite (A′),	63.70
Eutectic graphite (G′),	1.52
	100.00

or again,

	Per Cent.
Total austenite (A + A′),	98.48
Eutectic graphite,	1.52
	100.00

3. Alloys which contain more than 4.3 per cent. of carbon are made up after solidification of excess graphite (G), and some eutectic ($E = A' + G'$), and we have

$$(1) \; G + E = 100$$

$$(2) \; G + \frac{4.3}{100}E = R$$

in which R represents the known percentage of carbon.

If the alloy contains 5 per cent. of carbon, for instance, it should be composed after solidification of

	Per Cent.
Excess graphite (G),	0.73
Eutectic (E),	99.27
	100.00

and its ultimate composition will be, since the eutectic contains 2.35 per cent. of carbon,

	Per Cent.
Excess graphite (G),	0.73
Eutectic graphite (G′),	2.33
Eutectic austenite (A′),	96.94
	100.00

or again,

	Per Cent.
Total graphite (G + G′),	3.06
Eutectic austenite (A′),	96.94
	100.00

To test the accuracy of these figures—since the austenite contains 2 per cent. of carbon, 96.94 of austenite will contain 1.94 per cent. of carbon, which added to the 3.06 per cent. of graphite gives 5 per cent. as the total amount of carbon in the alloy.

II. *Composition after Slow Cooling.*

Four cases have now to be considered: (1) the alloy contains from 0 to 0.8 per cent. of carbon, (2) the alloy contains from 0.8 to 2 per cent. of carbon, (3) the alloy contains from 2 to 4.3 per cent. of carbon, (4) it contains over 4.3 per cent. of carbon.

1. If the alloy contains less than 0.8 per cent. it consists after slow cooling of some excess ferrite (F), and pearlite (P), which in turn is a mechanical mixture of ferrite and cementite (F′ C′).

We have

$$(1)\ F + P = 100$$

$$(2)\ \frac{0.80}{100} P = R$$

The percentage of ferrite and cementite in the eutectoid pearlite may readily be calculated as follows:

$$(a)\ F' + C' = 100$$

$$(b)\ \frac{6.67}{100} C' = 0.80$$

which gives $F' = 88$ and $C' = 12$.

If the alloy, for instance, contains 0.20 per cent. of carbon, then its proximate structural composition will be

	Per Cent.
Ferrite (F), ...	75
Pearlite (P), ...	25
	100

and its ultimate composition, since pearlite contains 12 per cent. of cementite, will be

	Per Cent.
Excess ferrite (F), ...	75
Eutectoid ferrite (F′), ...	22
Eutectoid cementite (C′), ...	3
	100

or again,

	Per Cent.
Total ferrite (F + F′), ...	97
Eutectoid cementite (C′), ...	3
	100

2. If the alloy contains from 0.8 to 2 per cent. of carbon, it is made up after slow cooling of (1) some excess cementite (C), and (2) some pearlite ($P = F' + C'$), and we have

$$(1)\ C + P = 100$$

$$(2)\ \frac{6.67}{100} C + \frac{0.80}{100} P = R$$

If the alloy contains, for instance, 1.50 per cent. of carbon, its proximate composition will be

	Per Cent.
Pearlite (P), ...	88.07
Excess cementite (C), ...	11.93
	100.00

and its ultimate composition

	Per Cent.
Eutectic ferrite (F′), ...	77.50
Eutectoid cementite (C′), ...	10.57
Excess cementite (C), ...	11.93
	100.00

or again,

	Per Cent.
Eutectoid ferrite (F′),	77.50
Total cementite (C + C′),	22.50
	100.00

3. If the alloy contains from 2 to 4.3 per cent. of carbon, it should be made up after slow cooling of (1) pearlite (P), (2) excess cementite (C), and (3) graphite from eutectic (G′), and we have

$$(1)\ P + C + G' = 100$$

$$(2)\ \frac{0.80}{100} P + \frac{6.67}{100} C + G' = R$$

The value of G′ is to be obtained from the composition of the metal after solidification.

If, for instance, the alloy contains 3.5 per cent. of carbon, then $G' = 1.52$, and the proximate composition will be

	Per Cent.
Pearlite (P),	78.35
Excess cementite (C),	20.13
Eutectic graphite (G′),	1.52
	100.00

and its ultimate structural composition

	Per Cent.
Eutectoid ferrite (F′),	68.95
Eutectoid cementite (C′),	9.40
Excess cementite (C),	20.13
Eutectic graphite (G′),	1.52
	100.00

or again,

	Per Cent.
Eutectoid ferrite (F′),	68.95
Total cementite (C + C′).	29.53
Eutectic graphite (G′),	1.52
	100.00

4. If the alloy contains over 4.3 per cent. of carbon, it is made up after slow cooling of (1) excess graphite (G), (2) eutectic graphite (G′), (3) pearlite (P), and (4) excess cementite (C), and we have the following relation between these constituents:

$$(1)\ P + C + G + G' = 100$$

$$(2)\ \frac{0.80}{100} P + \frac{6.67}{100} C + G + G' = R$$

the values of G and G′ being obtained from the composition of the metal after solidification, as explained above. If, for instance, the alloy contains 5 per cent. of carbon, then $G = 0.73$ and $G' = 2.33$, and the proximate composition of the alloy will be

	Per Cent.
Pearlite (P),	77.12
Excess cementite (C),	19.82
Total graphite (G + G′),	3.06
	100.00

and its ultimate composition

	Per Cent.
Eutectoid ferrite (F′),	67.87
Eutectoid cementite (C′),	9.25
Excess cementite (C),	19.82
Eutectic graphite (G′),	2.33
Excess graphite (G),	0.73
	100.00

or again,

	Per Cent.
Total ferrite (F + F′),	67.87
Total cementite (C + C′),	29.07
Total graphite (G + G′).	3.06
	100.00

In Fig. 3 of this paper an attempt has been made to give a graphical representation of the proximate structural composition, both after solidification and after slow cooling, of iron-carbon alloys.

The proximate and the ultimate structural composition of iron-carbon alloys, both after solidification and after slow cooling, will be found in Table III., for alloys containing between 0.10 and 5 per cent. of carbon.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Kjellin Electric Steel-Furnace.*

BY E. C. IBBOTSON, SHEFFIELD, ENGLAND.

(London Meeting, July, 1906.)

THIS process was reported upon by the Canadian Commission in 1904, and much detailed information was also given in a paper by Chief Engineer V. Engelhardt.[1] Believing that some of the latest particulars of the process will be of interest, I submit the following data.

At Gysinge in Sweden during the year ending May 31, 1906, from a fixed furnace giving 1 ton (2,240 lb.) of steel per tap, there were produced 950 tons of tool-steel and special steel ingots.

In carbon and iron tool-steels all the usual tempers were made. The bulk of this steel was made from charges composed of about 80 per cent. of Swedish white pig-iron and 20 per cent. of steel-scrap. The percentage of carbon was regulated by the addition of briquettes. Other charges were made from Swedish white iron and steel-scrap.

The average time taken per charge, for the year, when adding briquettes, was 7⅛ hr., and the electric energy consumed was 1,128 units (kilowatt-hours) per ton. The average time per charge for white-iron and scrap charges was 5.5 hr., and the electric energy consumed was 886 units per ton. These consumptions include all time and energy lost from various causes, such as bad water-supply, ice, etc.

It is quite ordinary practice to complete the charges with briquettes in 6.5 hr., and without briquettes in 5 hr., as shown by the following typical charges:

White pig-iron, 1,457; steel-scrap, 439; briquettes, 220; ferrosilicon (50 per cent. of silicon), 17; ferromanganese (80 per cent. of manganese), 15 lb.; and aluminum, 1 oz.

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* Presented at the Joint Meeting of the Iron and Steel Institute and the American Institute of Mining Engineers, London, July, 1906, and here published under a mutual agreement between the Councils of the two Institutes.

[1] *Stahl und Eisen*, vol. xxv., pp. 148 to 152, 205 to 212, 272 to 278 (1905).

The times, strength of current, and units consumed for this charge were as follows:

Time.	Current.		
	Kilowatts.	Units.	
5.30	125	......	Charging two-thirds of the pig-iron.
6.00	145	67.50	....
6.30	160	76.25	....
7.00	170	82.50	Charging the remaining one-third of the pig and the scrap.
7.30	170	85.00	....
8.00	165	83.75	Clear melted.
8.30	165	82.50	Briquettes added.
9.00	165	82.50	....
9.30	165	82.50	Briquettes added.
10.00	165	82.50	....
10.30	165	82.50	Briquettes added.
11.00	165	82.50	....
11.30	165	82.50	....
12.00	130	73.75	Ferrosilicon and ferromanganese added. Tapped.
6.5 hours.	......	1,046.25	

A second charge was made as follows:

Steel-scrap, 1,372; white iron, 914; ferrosilicon, 4.5; ferromanganese, 6.5 lb.; and aluminum, 1 oz.

The time was reduced, no briquettes being added. The results were as follows:

Time.	Current.		
	Kilowatts.	Units.	
7.00	125	......	Charging all pig and one-half scrap.
7.30	145	67.50	....
8.00	155	75.00	....
8.30	160	78.75	Charging scrap.
9.00	165	81.25	....
9.30	170	83.75	....
10.00	165	83.75	Clear melted.
10.30	165	82.50	....
11.00	165	82.50	....
11.30	165	82.50	....
12.00	135	75.50	Ferrosilicon and ferromanganese added. Tapped.
5 hours.	......	793.00	

The chemical compositions of the materials charged and of the resulting steel were as follows:

White-Iron (Herräng).

	Per Cent.
Total Carbon,	4.00
Silicon,	0.15
Manganese,	0.18
Sulphur,	0.010
Phosphorus,	0.012

Briquettes.

	Per Cent.
Iron,	59.0
Sulphur,	0.010
Phosphorus,	0.006
Silica,	11.00
Lime (CaO),	2.50
Alumina,	0.50

Steel Ingots.

	Per Cent.
Carbon,	0.40 to 2.00
Silicon,	0.12
Manganese,	0.34
Sulphur,	0.012
Phosphorus,	0.014

The lining of this furnace during the year was magnesite. When using briquettes the lining lasts, on an average, five weeks, and when charges are worked without briquettes the average life of the lining is seven weeks.

Various tests have been made of the steels produced in this furnace, and many have been given in previous reports. During the year satisfactory results obtained in works-practice have been reported, particularly in connection with the following steels: stamping-dies, punches, cold-chisels, screwing-dies and taps, cutlery, drills, and turning-tools. The following special steels have also been produced: tungsten steel (including permanent-magnet steel), chromium steel, nickel steel, nickel-chromium steel, self-hardening steel, and high-speed tool-steel. High-speed tool-steel, tested to one of the latest Government specifications, gave satisfactory results, while 25 per cent. unannealed 2-in. nickel-steel bar, 0.5 in. in diameter, gave a yield-point of 30.68 tons per sq. in., a maximum stress of 50.44 tons per sq. in., an elongation of 44 per cent., and a reduction of area of 60 per cent.

Electrical tests carried out have shown that No. 6 gauge rods had a specific resistance of 36 microhms per cu. in.; No. 16 gauge wire a specific resistance of 33.5 microhms per cu. in.

The form of tipping furnace, adopted and recently erected, is shown in Fig. 1. **A**, represents the primary coil; **B**, iron coil; and **C**, the bath (secondary circuit). The advantages of

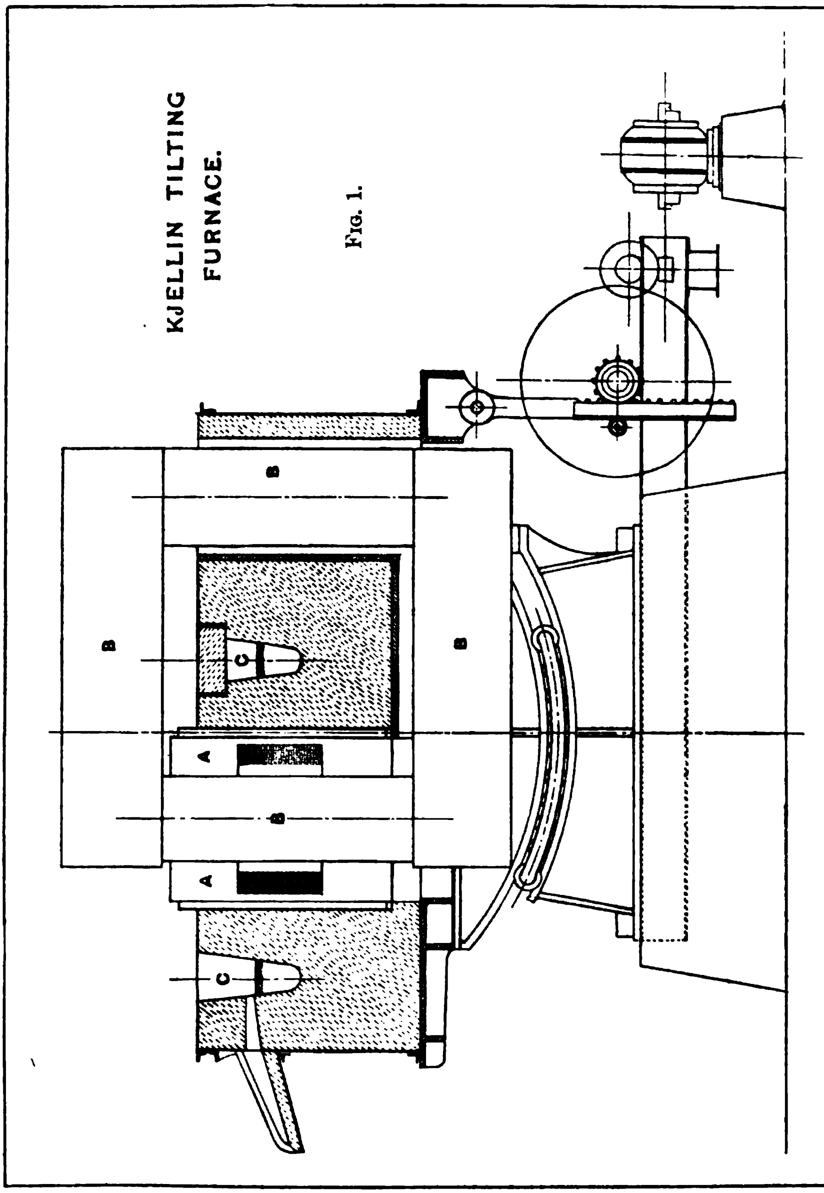

FIG. 1.

this furnace are that it can be tipped over the lip, or from the taphole, and can easily be repaired and relined when necessary.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Notes on Large Gas-Engines Built in Great Britain and Upon Gas-Cleaning.*

BY TOM WESTGARTH, MIDDLESBROUGH, ENGLAND.

(London Meeting, July, 1906.)

As papers are placed before you upon large gas-engines in Belgium and Germany, it was considered that some information should be given upon the same subject in Great Britain. I therefore agreed to compile these notes, which I have made very short in view of the somewhat full nature of the other papers presented to this meeting, and considering the complete nature of the many publications which have been made recently upon the subject of large gas-engines.

I give below Tables I. to VI., showing the number and particulars of large gas-engines which have been built or are building by British makers, and in view of the growing size of gas-engines I have concluded that engines less than 500 h.p. cannot now be included in the category of large gas-engines, and therefore I have not considered engines under that power.

TABLE I.—*"Oechelhäuser" Type Gas-Engines. Built or Building by William Beardmore & Co., Limited, Glasgow.*

No. of Engines.	Indicated Horse-Power Each.	Type.	Nature of Work.	Gas Used.
6	2,500	Twin cylinder.	Dynamo.	Producer.
1	1,850	Single cylinder.	Rolling-mill.	Producer.
4	1,250	Twin cylinder.	Dynamo.	Producer.
2	1,250	Single cylinder.	Dynamo.	Producer.
4	625	Single cylinder.	Dynamo.	Producer.
1	625	Single cylinder.	Rolling-mill.	Producer.
1	625	Single cylinder.	Air compressor.	Producer.
2	500	Single cylinder.	Air compressor.	Producer.
7	500	Single cylinder.	Cement-mill driving.	Producer.

Total, 28 engines ; 32,600 indicated horse-power.

* Presented at the Joint Meeting of the Iron and Steel Institute and the American Institute of Mining Engineers, London, July, 1906, and here published under a mutual agreement between the Councils of the two Institutes.

TABLE II.—*"Körting" Type Gas-Engines. Built by Mather & Platt, Limited, Manchester.*

No. of Engines.	Indicated Horse-Power Each.	Type.	Nature of Work.	Gas Used.
1	1,250	Twin cylinder.	Dynamo.	Duff producer.
2	875	Single cylinder.	Dynamo.	Mond producer.
2	625	Single cylinder.	Dynamo.	Duff producer.
1	625	Single cylinder.	Flour-mill.	Mond producer.

Total, 6 engines ; 4,875 indicated horse-power.

TABLE III.—*"Premier" Type Gas-Engines. Built or Building by the Premier Gas-Engine Co., Limited, Nottingham.*

No. of Engines.	Indicated Horse-Power Each.	Type.	Nature of Work.	Gas Used.
2	1,100	Tandem, single-acting.	Dynamo.	Bituminous producer.
1	1,000	Tandem, single-acting.	Blowing.	Blast-furnace.
5	650	Tandem, single-acting.	Dynamo.	Bituminous producer.
4	600	Tandem, single-acting.	Dynamo.	Bituminous producer.
1	600	Tandem, single-acting.	Rolling-mill.	Bituminous producer.
11	500	Tandem, single-acting.	Dynamo.	Bituminous producer.
2	500	Tandem, single-acting.	Dynamo.	Coke-oven.
1	500	Tandem, single-acting.	Paper-mill.	Bituminous producer.
1	500	Tandem, single-acting.	Dynamo.	Blast-furnace.

Total, 28 engines ; 16,950 indicated horse-power.

TABLE IV.—*Gas-Engines Built by Willans & Robinson, Limited, Rugby.*

No. of Engines.	Indicated Horse-Power Each.	Type.	Nature of Work.	Gas Used.
2	900	Tandem, double-acting.	Dynamo.	Mason producer.

Total, 2 engines ; 1,800 indicated horse-power.

TABLE V.—*Gas-Engines Built or Building by Crossley Bros., Limited, Manchester.*

No. of Engines.	Indicated Horse-Power Each.	Type.	Nature of Work.	Gas Used.
4	700	Single-acting, *vis-à-vis.*	Alternators.	Producer.
4	700	Single-acting tandem.	Pumping.	Producer.
4	625	Single-acting, *vis-à-vis.*	Pumping.	Coal-gas.
2	610	Four-cylinder single-acting, *vis-à-vis.*	Alternators.	Coal-gas.
5	560	Single-acting, *vis-à-vis.*	Electrolytic work.	Producer.
1	560	Single acting, *vis-à-vis.*	Wire-works.	Producer.
1	560	Single-acting, *vis-à-vis.*	Bleach-works.	Producer.
1	560	Single-acting tandem.	Flour-mill.	Producer.
1	560	Single-acting, *vis-à-vis.*	Blowing.	Blast-furnace.
2	500	Single-acting, *vis-à-vis.*	Electric lighting.	Producer.
2	500	Single-acting tandem.	Electric lighting.	Producer.
1	500.	Single-acting, *vis-à-vis.*	Electric lighting.	Coke-oven.
2	500	Single-acting, *vis-à-vis.*	Electrolytic work.	Producer.
1	500	Single-acting, *vis-à-vis.*	Electric tramway.	Producer.
1	500	Single acting, *vis-à-vis.*	Cotton-mill.	Producer.
1	500	Single-acting, *vis-à-vis.*	Mining machinery.	Producer.

Total, 33 engines; 19,360 indicated horse-power.

TABLE VI.—"*Cockerill" Type Gas-Engines. Built or Building by Richardsons, Westgarth & Co., Limited, Middlesbrough.*

No. of Engines.	Indicated Horse-Power Each.	Type.	Nature of Work.	Gas Used.
2	1,500	Twin tandem, double-acting.	Tube-rolling mills.	Mond producer.
2	1,500	Twin tandem, double-acting.	Dynamo.	Mond producer.
1	1,000	Tandem, double-acting.	Tube-rolling mill.	Mond producer.
2	950	Tandem, double-acting.	Dynamo.	Blast-furnace.
10	800	Single cylinder, single-acting.	Blowing.	Blast-furnace.
1	800	Tandem, single-acting	Mine fan.	Coke-oven.
2	750	Tandem, double acting.	Dynamo.	Mond producer.
1	650	Tandem, double-acting.	Dynamo.	Mond producer.
1	650	Tandem, double-acting.	Dynamo.	Blast-furnace.

Total, 22 engines; 20,500 indicated horse-power.

It will be observed no mention is made in Tables I. to VI. of engines built by Messrs. Hornsbys of Grantham, Rodger & Co. of Glasgow, Campbell of Halifax, Fielding & Platt of Gloucester, the National Company of Ashton-under-Lyne,

Tangyes of Birmingham, or the Westinghouse Company of Manchester, which is accounted for by the fact that none of these firms have as yet built engines of 500 h.p. or upwards, although they are all building engines of fair size.

It will be noticed that all the British builders of large gas-engines are using the "four-cycle" system, except the builders of Körting and Oechelhäuser engines, who work upon the "two-cycle" system. It will also be noticed that large gas-engines are gradually coming into use in Great Britain for general purposes; *i.e.*, in addition to blowing and dynamo work, they are being applied to rolling-mills and for general manufacturing purposes, cotton-mills, cement-works, etc.

To illustrate the extent to which gas-engines of large size are now being used in Great Britain, I have included in the paper illustrations of some of the principal installations in the country.

Fig. 1. shows the installation of Oechelhäuser engines built by Messrs. Beardmore for their new shipyard at Dalmuir. This installation is of 6,625 i.h.p. in seven units.

Fig. 2. shows part of an installation of Körting engines by Messrs. Mather & Platt, consisting of two 875-i.h.p. engines now running at a chemical works.

Fig. 3. Engines supplied to Messrs. Bayliss, Jones & Bayliss by the Premier Co., the engine in the foreground being of 650 h.p.; the other engines are less than 500 h.p., and therefore do not come within the scope of this paper.

Fig. 4. One of a pair of 900-i.h.p. engines built by Messrs. Willans & Robinson, and running at Reading.

Fig. 5 is an illustration of one of Messrs. Crossley Brothers, latest engines, of 625 i.h.p.

Fig. 6 shows a large installation of gas-driven blowing engines built by Messrs. Richardsons, Westgarth & Co., Limited, of Middlesbrough, for the Cargo Fleet Iron Co., Limited. There are seven engines, of a total of 5,600 i.h.p.

Fig. 7 shows Messrs. Richardsons, Westgarth & Co.'s latest type of tandem double-acting gas-engines for dynamo and general work, and is shown as illustrating the latest development in this type of engine; the arrangement being one which, with alteration in detail, has been adopted generally by all the principal makers of gas-engines working on the "Otto" cycle.

Fig. 1.—Oechelhäuser Engines Built by William Beardmore & Co., Ltd.; 6,625 i.h.p. in Seven Units.

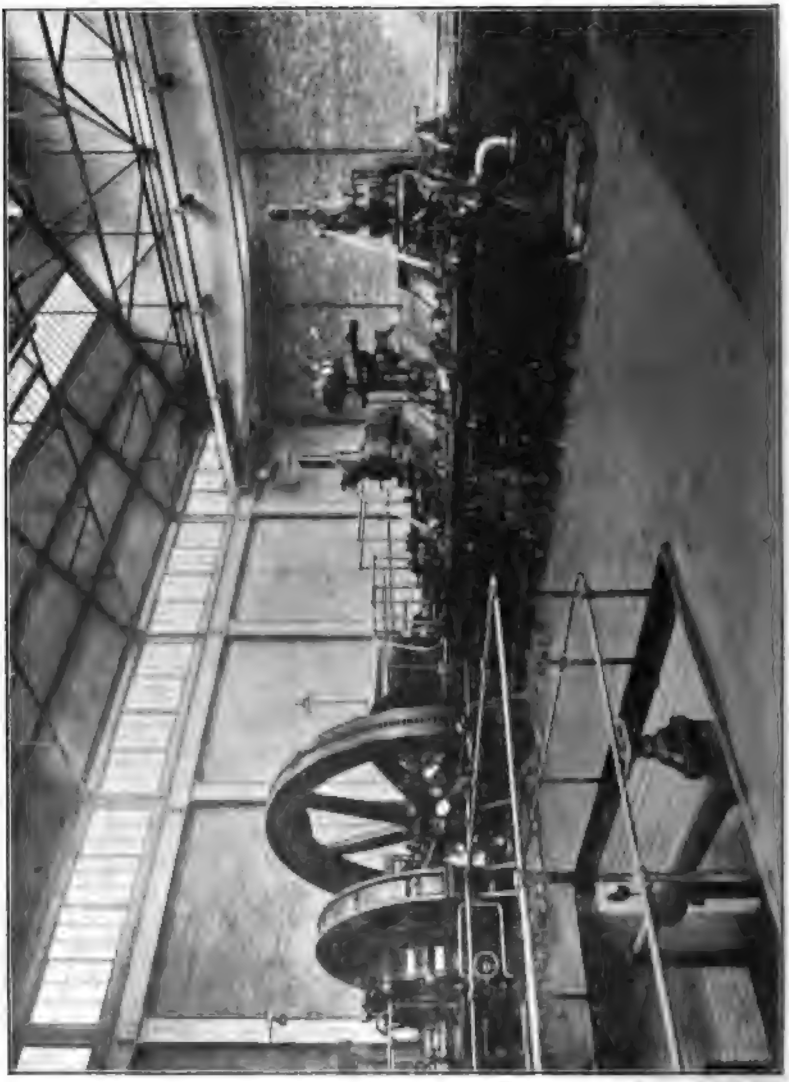

Fig. 2.—Two 875-i.h.p. Körting Engines Built by Mather & Platt, Ltd.

Fig. 3.—650-h.p. Engine Built by the Premier Gas-Engine Co., Ltd.

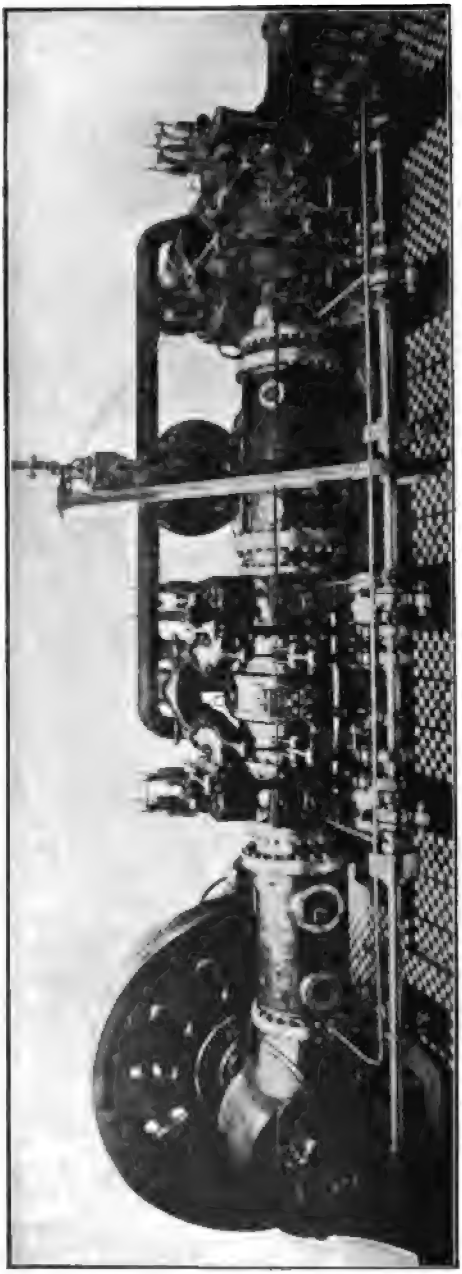

FIG. 4.—900-H.P. ENGINE BUILT BY WILLANS & ROBINSON, LTD.

Fig. 5.—625-i.h.p. Engine Built by Crossley Bros., Ltd.

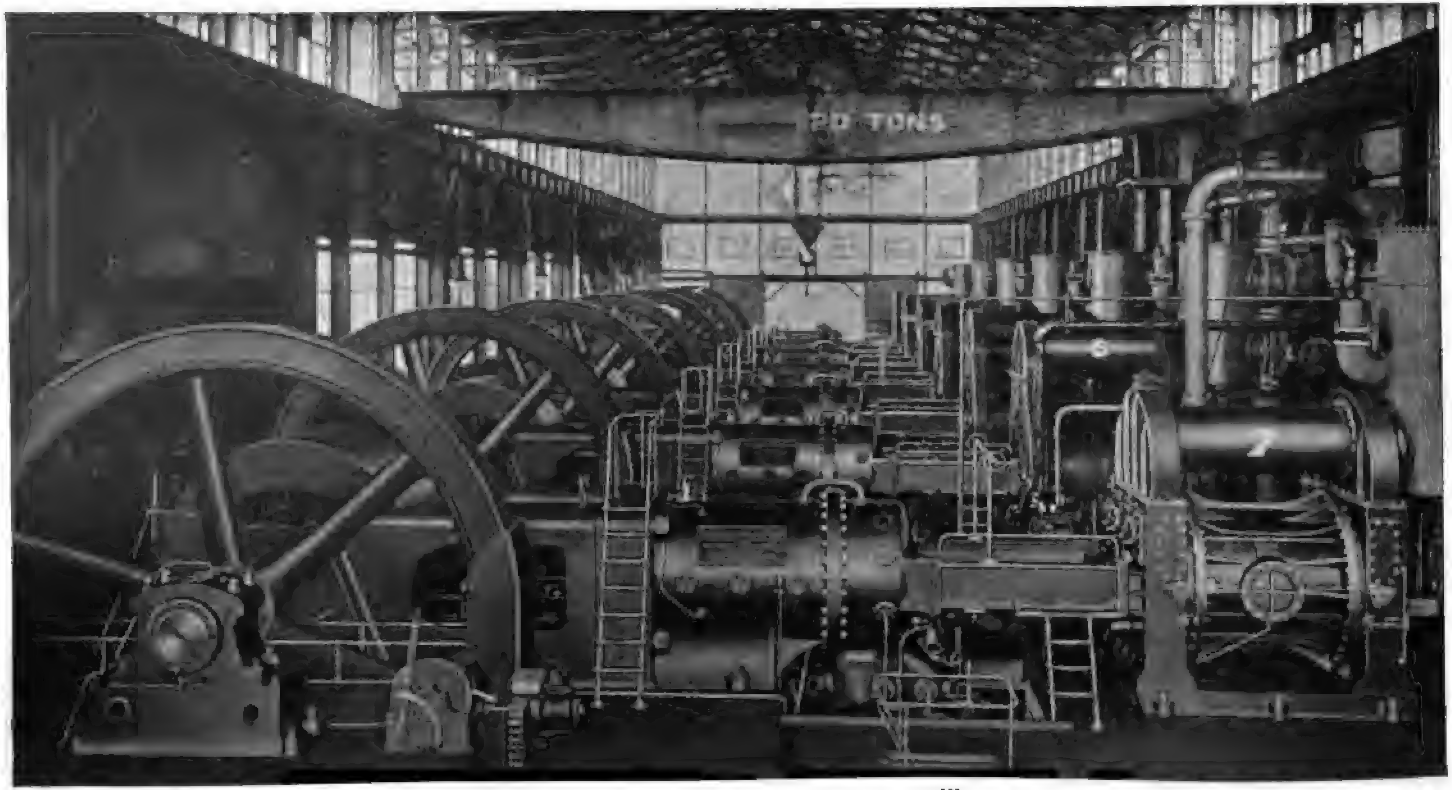

FIG. 6.—GAS-DRIVEN BLOWING-ENGINES BUILT BY RICHARDSONS, WESTGARTH & CO., LTD.

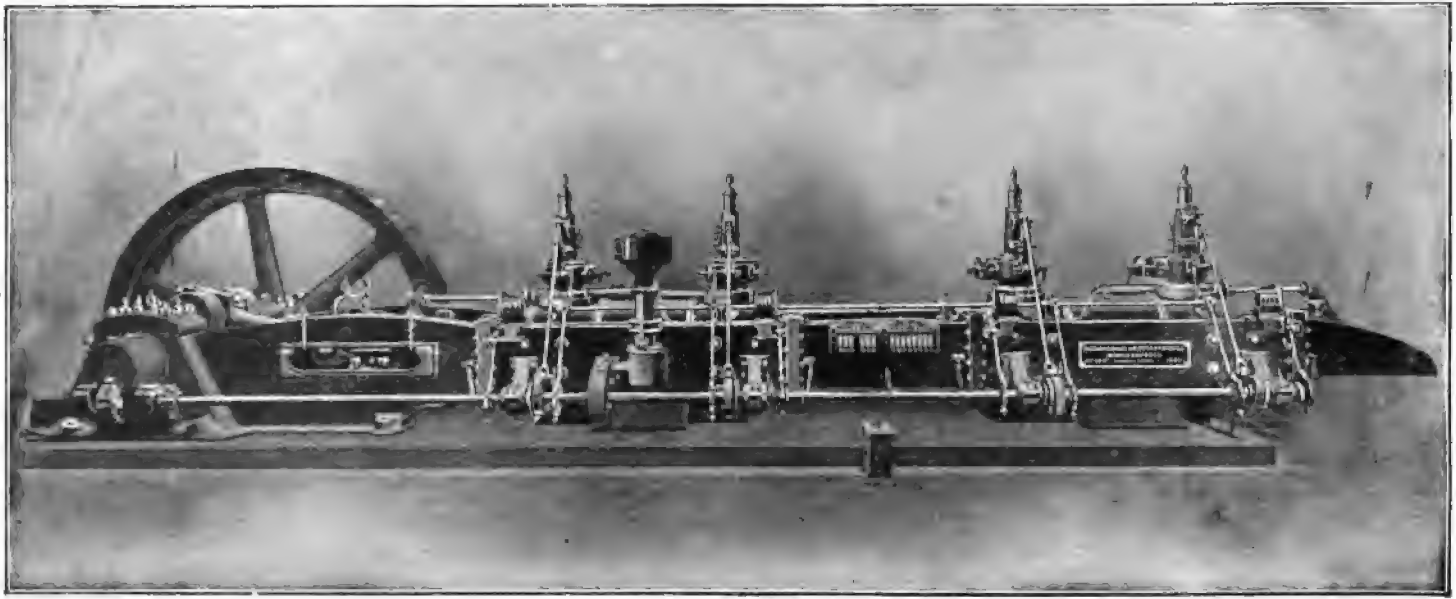

Fig. 7.—Tandem Double-Acting Gas-Engine Built by Richardsons Westgarth & Co., Ltd.

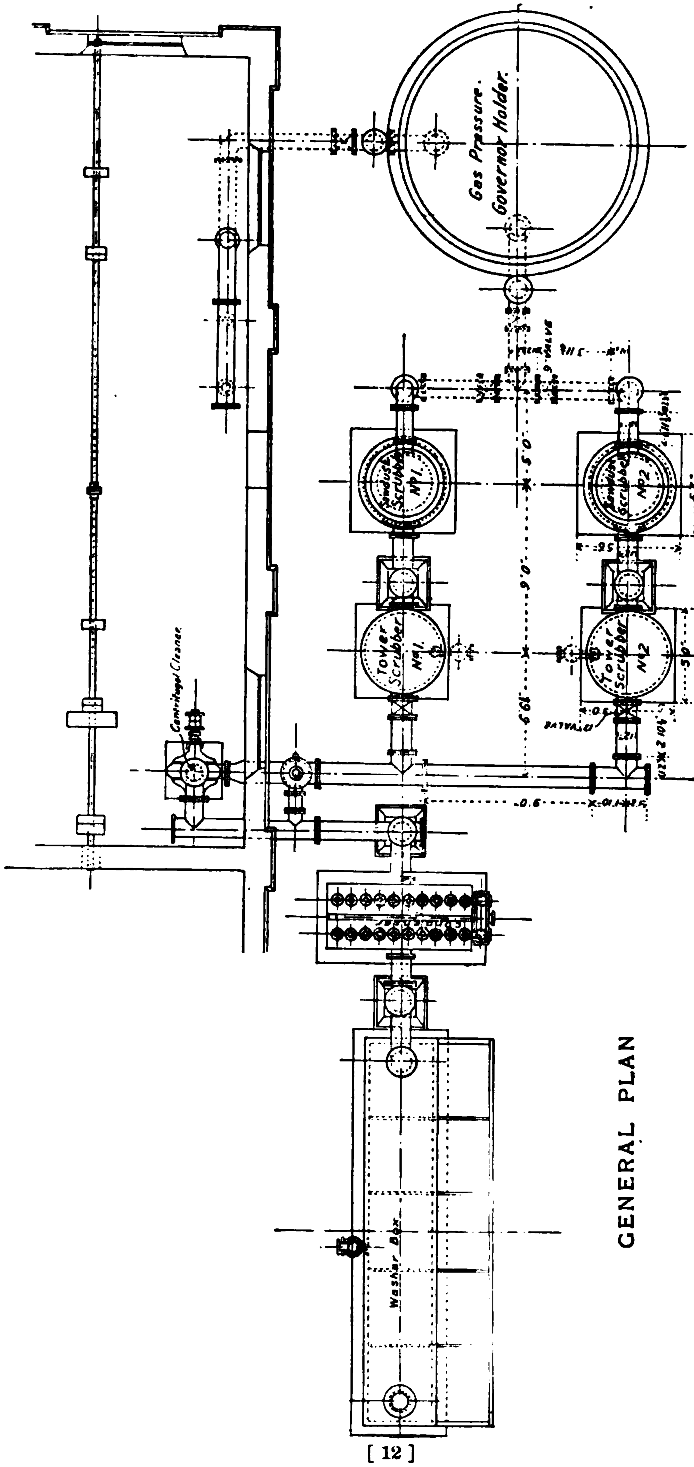

FIG. 8.—"THWAITE" B. F. GAS CLEANING PLANT INSTALLED IN 1889 AT THE SHEEPBRIDGE IRON CO.'S WORKS.

Fig. 9.—Gas-Cleaning Apparatus for Producer-Gas Built by the Power-Gas Corporation.

FIG. 10.—GAS-CLEANING APPARATUS FOR PRODUCER-GAS BUILT BY MASON'S GAS POWER CO., LTD.

It is thought that any notes upon large gas-engines in Great Britain should be accompanied by a reference to gas-cleaning, this being such an important matter in connection with the proper running of the engines.

Most engineers commenced cleaning the gas for engines by passing it through ordinary fans with water. It was soon found that two or more fans in series would be necessary, and that a considerable quantity of water and much power was required, the result not always being satisfactory, particularly if the gas had not previously been very well cleaned and cooled by passing through large dust-catchers and long mains. A difficulty also occurs with the moisture absorbed by the gas in the fans, and it has been found necessary to supplement the fans by various cleaning and drying devices.

One of the pioneers in dealing with the cleaning of gas for engines was Mr. B. H. Thwaite, and Fig. 8 gives particulars of his apparatus, which is cleaning blast-furnace gas at Sheepbridge. A similar plant is also working at Ardsley.

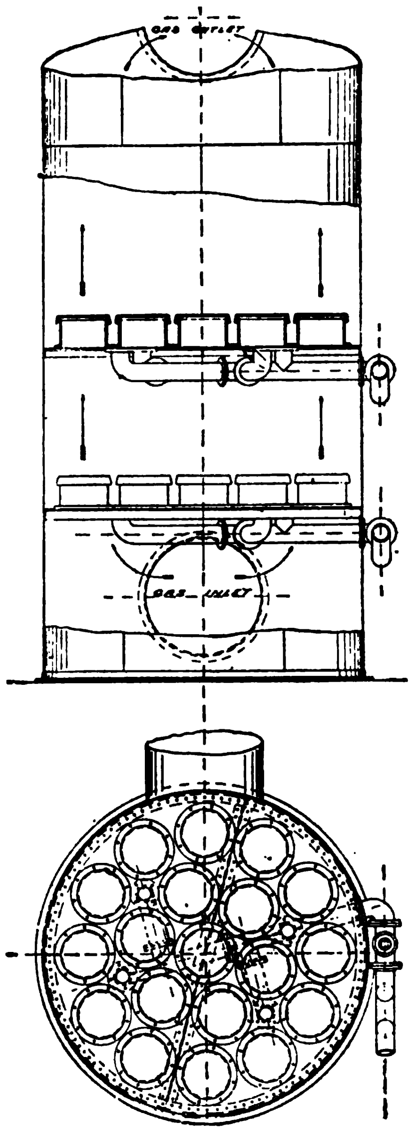

FIG. 11.—TAR-EXTRACTION APPARATUS OF THE SUMERLEE COMPANY.

Other methods of cleaning the gas upon much the same lines have been worked out in connection with producer-gas by The Power Gas Corporation of Westminster, and Mason's Gas Power Co., Limited, of Manchester. Fig. 9 shows one of the

Power Gas Corporation's installations erected at West Gorton, and Fig. 10 a plant erected by Mason's Company at Reading. It will be observed that in both cases fans are used in conjunction with cooling towers, etc.

Fig. 11 illustrates the Sumerlee Company's patent apparatus for extracting the tar from gas after it has passed through a by-product recovery plant.

Figs. 12 and 12A represent a large installation of Theisen's Patent Gas-Cleaning Apparatus, erected at the Cargo Fleet Company's works, by Richardsons, Westgarth & Co., Limited, of Middlesbrough, which shows the latest practice in cleaning blast-furnace gas. This apparatus is able to clean ordinary blast-furnace gas down to 0.002 g. per cu. m. with the use of less than 1 liter of water per cu. m. of gas. It will be observed that a vapor separating apparatus is fitted to the outlet of the Theisen cleaner, which has the effect of thoroughly drying the gas.

I have not entered into any detailed description of the various gas-cleaning apparatus named above, my object in these notes being merely to call attention to the various systems for the benefit of those who require general information. Nor have I made any mention of Zschocke, Bian, or Sahlin gas-cleaning plants, because, although these are receiving some attention in this country, they have not been used here so far as I know.

FIG. 12.—THIESEN'S GAS-CLEANING APPARATUS AT THE CARGO FLEET IRON COMPANY'S WORKS.

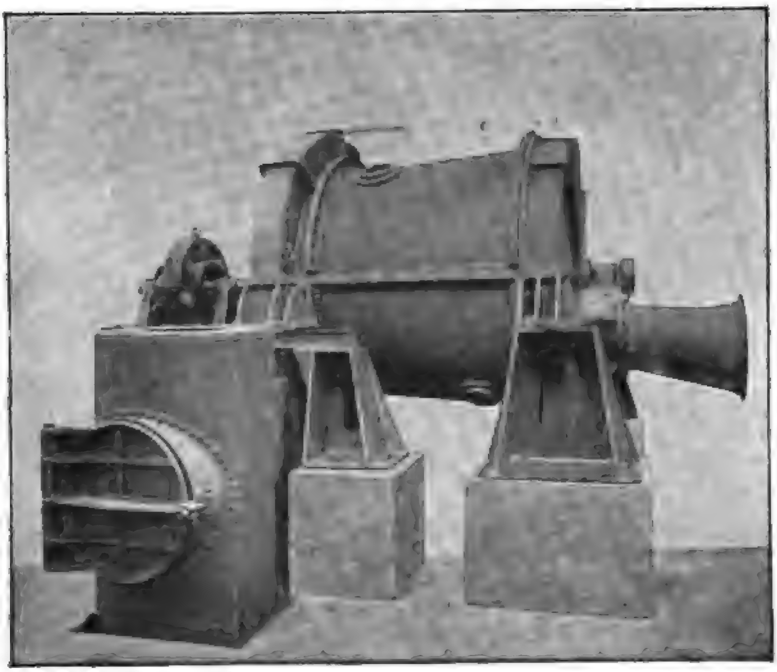

FIG. 12A.—THIESEN'S GAS-CLEANING APPARATUS.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Crystallography of Iron.*

BY F. OSMOND AND G. CARTAUD, PARIS, FRANCE.

(London Meeting, July, 1906.)

I. INTRODUCTION.

WE have already devoted two previous memoirs to this question. In the first[1] we collated and discussed the existing literature on the subject; in the second,[2] we described the crystalline forms obtained by the reduction, at different temperatures, of ferrous chloride by hydrogen or by zinc-vapor. The conclusion from these researches was that the three allotropic states of iron—α, stable below $A2$; β, stable between $A2$ and $A3$; and γ, stable above $A3$—all crystallize in the cubic system. The differences observed were such as are customarily encountered in the crystallographic records of many minerals of which allotropic varieties or isomerides are not known, but did not conform to the ordinary definition of polymorphism.

It is, however, improbable that allotropic transformations, which are placed beyond doubt by a series of positive facts, do not involve some changes in the intimate structure.

As a matter of fact, the crystals we did obtain were too small to allow of a precise examination, and this might introduce an element of uncertainty in the firm establishment of our conclusions. Professor H. Le Chatelier was even led to think from some of our results that γ-iron could very well be a rhombohedron simulating a cube, and not a true cube, and it will be remembered that the crystalline form of bismuth was for a long time incorrectly regarded as cubic.

Allotropy does not, however, necessarily involve such a deduction. Without departing from the cubic system at all, a whole

* Presented at the Joint Meeting of the Iron and Steel Institute and the American Institute of Mining Engineers at London, July, 1906, and here published under a mutual agreement between the Councils of the two Institutes.

[1] *Annales des Mines*, vol. xvii., pp. 110 to 165 (1900).

[2] *Ibid.*, vol. xviii., pp. 113 to 153 (1900).

series of variants may be found incompatible among themselves, and yet compatible with the same external forms. But as a study of the latter would scarcely lead to conclusive results concerning the structure of iron, other methods had to be sought to solve the question.

Optical methods are not available, but the morphological and other characters capable of yielding useful information are as follows:

1. Deformation figures:
   Continuous (*a*).
   Discontinuous (effaceable: lines of translation and folding (*b*); not effaceable: mechanical twinning (*c*).
2. Congenital twinning.
3. Twinning resulting from annealing after deformation.
4. Mechanical properties functional of the crystalline orientation.
5. Corrosion figures.
6. Synchronous crystallization figures.
7. Segregation figures.

Before we describe our experiments and the results of our observations, we shall indicate the principles of these different methods, some of which are but slightly known.

1. *Deformation Figures.*

In a paper published in collaboration with Mr. Frémont[3] we have expressed the opinion that a crystalline body may in a sense be considered both as cellular and amorphous; the former in so far as it is formed of polyhedral grains, each of which is a crystalline element of definite orientation, and the latter when the deformations are only governed by the direction of the strains and are independent of the crystalline structure.

Whence arise three kinds of deformation, which may be called crystalline, cellular, and banal. In the present work the question of cellular deformation will not arise, as our operations are restricted to isolated crystals. We are chiefly engaged in crystalline deformations. With regard to banal deformations, we shall not study them for their own sake, but only as distinctive characters when we encounter them in course of work.

[3] *Revuede Métallurgie*, vol. i., pp. 11 to 45 (1904).

Every deformation has some sort of general configuration, which may be called its silhouette, and which is the boundary of elementary deformations. It is the area of a previously polished body that loses its polish when the deformation takes place. A silhouette is naturally continuous and closed. Its form on an ordinary metal with cellular structure depends only on the form of the sample and on the nature or direction of the strains; but it ceases to be the same on an isolated crystal, for then its form can be in relation with the crystalline symmetry.

1 (*a*). *Continuous Crystalline Deformations; Silhouettes.*—If a sharp conical point is applied to a flat surface of a plastic crystal previously polished, from which all skin-hardening has been removed, a permanent deformation is obtained around the cone of penetration, the silhouette of which is not circular, as it would be on an amorphous or finely grained bed, but it presents a definite form characteristic of, firstly, the crystallographic system to which the crystal belongs, and secondly, of the crystallographic orientation of the surface concerned.

These silhouettes can therefore give at least two kinds of information; that is, they can indicate the system of crystallization to which a crystalline body belongs, if that knowledge is required, or if the system is already known they can approximately orient a slice of unknown orientation.

1 (*b and c*). *Discontinuous Deformations.*—Total deformation inclosed in the perimeter of a silhouette is an assemblage of elementary deformations which, in part at least, are discontinuous and in lines. The lines may be straight or curved. In crystalline bodies the straight lines generally have a definite crystallographical orientation. These lines, when obliterated by polishing, may or may not reappear after the repolished surface is etched by a suitable reagent.

It is generally admitted that a crystalline body is an aggregate of identical molecular polyhedra of the same orientation, and having their centers of gravity at the intersections of a reticulated complex.[4]

Now, it is an acknowledged fact that in a given crystalline body certain definite reticulate planes T (Fig. 1, in perspective), called planes of translation, are susceptible to displacement

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[4] De Lapparent, *Cours de Minéralogie:* p. 21. (Masson. Paris, 1899).

parallel to themselves by sliding the length of one of their ranges, t, and this can take place without causing rupture. The reticulated plane, P, conjugate of T and passing by the range, t, is called the sliding-plane (*plan de poussée;* in German, *Schiebungsebene*).

Let us suppose that the plane of translation and the sliding-plane are rectangular, and that the sliding-plane is a plane of symmetry of the system. Let $A\,B\,C\,D$ be a mesh of this sliding-plane (Fig. 2), $A\ B$ and $C\,D$ being parts of two immediately adjoining planes of translation. If a movement of translation takes place, while $C\,D$ remains fixed, $A\ B$ could slide on itself.

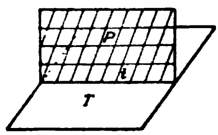

FIG. 1.—PLANE OF TRANSLATION.

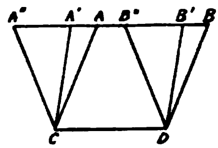

FIG. 2.—SLIDING-PLANE.

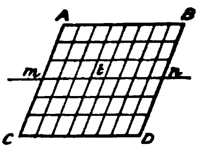

FIG. 3.—SIMPLE TRANSLATION.

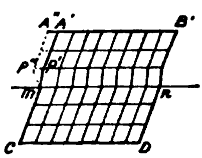

FIG. 4.—MECHANICAL TWINNING.

In this movement two conditions may arise. First, $A\ B$ moves to $A'B'$, A' being any point in the direction $A\ B$, and the molecular polyhedra, of which the centers of gravity coincide with the intersections A and B, retain their initial orientation after displacement. There is only a change in the form of the mesh $A\ B\ C\ D$, which is now in a condition of unstable equilibrium. This would be called a simple translation. Second, $A\ B$ moves to $A''\ B''$, in a position symmetrical with its original position, and, at the same time, the displaced molecular polyhedra also assume the orientation symmetrical with their first orientation, with reference to a plane perpendicular to the direction of translation. In this case mechanical twinning ensues.

The translation, with or without the formation of twins,

gives place to the appearance of little straight steps on the exterior faces of the crystal, and these steps are parallel to the lines of the planes of translation. If $A\ B\ C\ D$ (Fig. 3) be a portion of the sliding-plane, let us suppose that, the part $C\ D\ m\ n$ remaining stationary, the plane of translation immediately adjoining $m\ n$ is displaced for a short distance, involving the upper part of the system. The terminal lines $A\ C$, $B\ D$ will take the profile $C\ m\ p'A'$ if the translation is simple, or $C m p'' A''$ if there is mechanical twinning (Fig. 4).

To distinguish a line of translation from a mechanical twin crystal, the deformed face must be repolished and etched by a suitable reagent. Lines of translation are not in evidence, because the molecular polyhedra have retained their orientation; the macle, on the other hand, shows up—it has a definite thickness, its planes of junction are depressed, and its corrosion figures are not the same as those of the initial crystal, since the orientation of the molecular polyhedra has been modified.

The notion of translation can easily be generalized. It is, in fact, probable that the so-called planes of translation are only the planes of easiest translation, and that when the faculty of deformation in the direction of these planes is exhausted, others enter into action in their turn. Imagine, then, that the mesh, $A\ B\ C\ D$ (Fig. 2), after having been transformed by simple translation from one parallelogram into another, susceptible of conserving an unstable equilibrium, can, by other movements of translation, change into a quadrilateral—the only condition being that the area remains constant, inasmuch as the density does not change. Ultimately, when all the meshes of a crystalline body are dislocated in this manner, it becomes in a way decrystallized, and this explains the curved deformations (folds, or plissements).

These views on deformation of crystals, still comparatively little known, appear to have originated from the celebrated experiments of Reusch and Baumhauer, on the mechanical twinning of calcite. Simple translation was introduced into science by a long series of notes due to Mr. Mügge, and published for the most part in the *Neues Jahrbuch für Mineralogie.* Mr. Mügge's researches date back to 1884 at least, but his first work was on minerals, and it was only in 1899 that he took up

native metals.[5] The same year Prof. Ewing and Mr. Rosenhain undertook, independently, the study of the industrial metals, and in a remarkable memoir,[6] which has been followed by many more, were developing from their side the idea of translation. In the preceding considerations we have only advanced a tentative personal interpretation, ascribing to a single cause lines of translation, twinning, and folding. If we do not retain, in this instance, the term slip-bands proposed by Prof. Ewing and Mr. Rosenhain, it is because this term includes both lines of translation and the folds, between which we consider it useful to make a distinction.

In the case of bodies belonging to the same crystallographical system, the position of the planes of translation and of mechanical twinning, and also the presence or the absence of folds, furnish many very valuable differentiation characters.

2. *Congenital Twinning.*

We give this name to the twinning which takes place spontaneously during the progress of crystallization, just when the solid molecules are becoming isolated from the liquid medium which holds them in a state of fusion or in solution.

3. *Twinning Resulting from Annealing after Deformation.*

This twinning results, as the name indicates, from the annealing for a sufficiently long time and at a sufficiently elevated temperature of a crystalline solid previously deformed.

This twinning might be susceptible of relation with mechanical twinning and the phenomena of translation. If, for example, translation has moved the point A (Fig. 2) to the vicinity of the symmetrical point A'', but without the molecular polyhedron, which has its center of gravity at A'', having assumed the orientation corresponding to the new position of the system, annealing, when widening the molecular intervals, could render the molecular polyhedron A free to assume the position of twinning equilibrium, which, as a result of the deformation, the system alone had taken, or nearly so. The twinning will only then be consummated. Provided matters actually pro-

[5] *Neues Jahrbuch für Mineralogie*, vol. ii., p. 55 (1899).

[6] *Transactions of the Royal Society*, vol. cxcv., p. 279.

ceed in this fashion, the annealing simply completes the work of deformation.

4. *Mechanical Properties Functional of the Crystalline Orientation.*

The possible variations in these properties result from the very definition of the crystalline structure. It has been a known fact for a long time that the cleavage-faces are faces of minimum hardness, that on the same face the hardness varies with the direction and along the same direction with the sense of the striation.

5. *Synchronous Crystalline Figures.*

When a body is caused to crystallize on a crystalline face of another body, it occasionally happens that the structure of the latter orients the molecules of the crystallizing body to the extent that, as they separate from the bath, it imposes upon them a pseudosymmetry which does not naturally belong to them. These anomalies[7] can eventually give certain indications concerning the crystallography of the dominant body.

6. *Segregation Figures.*

When a body, liquid or solid, deposits several successive solid phases, the deposits of the second or third consolidation frequently settle by preference between certain definite crystallographic planes of the deposit from the first consolidation, and in this way show up its structure.

These planes between which the segregation takes place are probably the planes of maximum separation, or, which comes to the same thing, planes of the greatest reticular density.

II. Experimental Section.

Such are the methods we have used or attempted to use.

All of them, of course, have not furnished results which could be used for the end we had in view—that is to say, means of diagnosis applicable to the different varieties of iron. Whether by reason of their inappropriateness, or because we did not know how to make use of them, certain of them have

[7] See an article by M. Wallerant: *Bulletin de la Société française de Minéralogie*, Aimée, p. 180 (1902),

given negative results. This will not deter us from describing any facts observed, whether positive or negative, which could suggest ideas for fresh experiments to other workers.

We must evidently work for each of the allotropic varieties of iron within those limits of temperature where the particular variety is stable.

For α-iron there is no difficulty, since ordinary temperature is within the range of stability.

For β-iron, which cannot be wholly kept in unstable equilibrium, temperatures between 750° and 855° C. (we retain the temperatures indicated in our preceding publications. To take into account the new pyrometric standards, these figures must be raised to about 780° and 890° respectively—that is to say, to the figures given by Roberts-Austen or by Carpenter) are required, as far as possible about the middle of the interval, in the neighborhood of 800°. Besides, a crystal of α-iron heated in the range of β-iron, and cooled to the ordinary temperature, becomes again the same crystal of α-iron—the system persists beyond transformation $A2$.

This is not the case with the passage of the point $A3$, provided it has been sufficiently exceeded, and for a sufficiently long time. It is quite possible, if the heating and the cooling down are both done rapidly, to heat a crystal of α-iron up to 900° without destroying it; but if it is maintained at this temperature, the crystal resolves itself into little grains, with the formation of elongated lamellæ, which appear to be twin crystals. Fig. 5 is a photomicrograph (100 diameters) of face $p(001)$ of a crystal of iron, after two hours' heating at about 1,000°; etched, after repolishing, by alcoholic picric acid; the sides of the photomicrograph are parallel to the sides of the square of the original crystal.

It is therefore preferable for the study of the crystallography of γ-iron to resort to the alloys of iron with carbon and manganese, nickel or chromium; naturally selecting from these alloys those that are not magnetic at the ordinary temperature.

In all cases it is expedient to have the crystals as large as possible.

As regards α- and β-irons, thanks to the generosity of Professor Tschernoff, we had at our disposal a beautiful specimen

from an open-hearth furnace, with large cubic cleavages, containing C, 0.05; P, 0.30; Mn, 0.00 per cent.

Another sample, still more remarkable, was procured for us by Mr. Werth, director of the metallurgical works of Denain and Anzin. It consists of the fragments of an old steel rail, which during 15 years has served as a guide to a damper in a furnace-chimney, and of which certain parts had during this long period of time been submitted to conditions favorable to the development of crystals. That is to say, in accordance with Mr. Stead's excellent work,[8] to a temperature slightly inferior

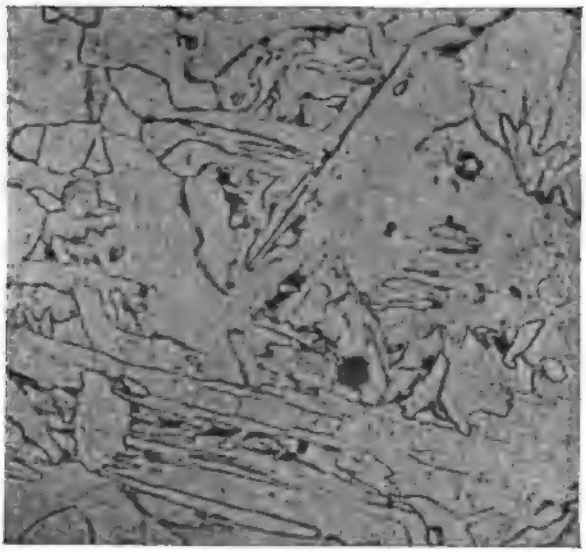

Fig. 5.—Face $p(001)$ of a Crystal of Iron Heated for Two Hours to 1,000° C., Polished and Etched.

to $A2$. Chemical analysis of the sample made in the laboratory at Denain yielded C, 0.06; Si, 0.05; S, 0.02; P, 0.116; Mn, 0.30 per cent. Yet the amount of carbon found must be above the mean, inasmuch as we have encountered no traces of cementite in the numerous sections we have made, and the other oxidizable elements are to a great extent scorified away, so that the metal is almost pure iron, in crystals, of which some attain a magnitude of several cubic centimeters.

For γ-iron we have used a fragment of ordinary cast man-

[8] *Journal of the Iron and Steel Institute*, vol. liii., No. 1, p. 145 to 189 (1898).

ganese steel, which Mr. Hadfield kindly had taken from the interior of an ingot, in the region of final consolidation. Another sample came to us from the Imphy Steel Works, and contained C, 0.15; Si, 0.30; P, 0.023; Mn, 0.23; Ni, 24.80; Cr, 2.21 per cent. Although special precautions had been taken to delay the cooling, this sample, which was in the form of a round bar, presented a comparatively fine grain inappropriate

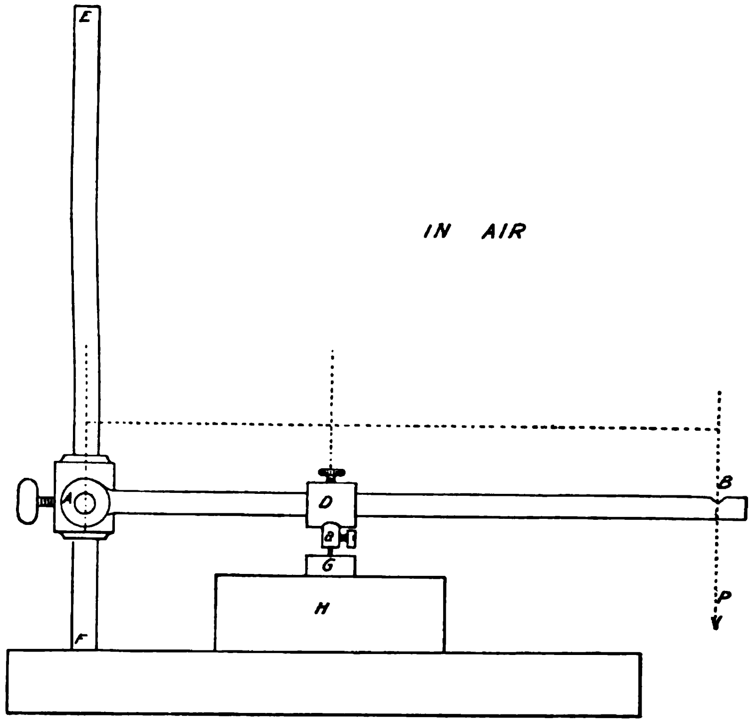

FIG. 6.—DEFORMATION-APPARATUS FOR USE IN AIR.

for crystallographic researches. We deformed a piece of it which had been annealed at about 1,300°, and obtained equiaxial grains of a mean diameter of 1 mm. Mr. Hadfield's manganese steel, on the contrary, showed on fracture distinct crystallites with rectangular branches. It is known that the axes of a crystallite in the cubic system are the quaternary axes of the cube; consequently it was possible to cut sections with a known crystallographical orientation.

1 (*a*). *Continuous Crystalline Deformation; Silhouettes.*

The principle of the method has been described above. A sewing-needle served for the tests at the ordinary and at lower temperatures; it was broken, and a point perfectly acute, with an angle of about 60°, was remade at the hardest part by rubbing on emery-papers of increasing degrees of fineness.

This needle, *a* (Fig. 6), is fixed by a vise in a socket, *D*, which can slide along the lever, *A B*, and be fixed at any point in its length. The lever, *AB*, is articulated at *A* on a movable guide along the vertical arm, *E F*. To obtain a silhouette by the pressure of the point on a polished crystallographical face, the prepared specimen, *G*, is placed on the support, *H*, in such a way that the polished face is horizontal. *A* is moved the length of *E F* until the lever, *A B*, is also horizontal and the point just meets the piece *G*. Then suitable weights are sus-

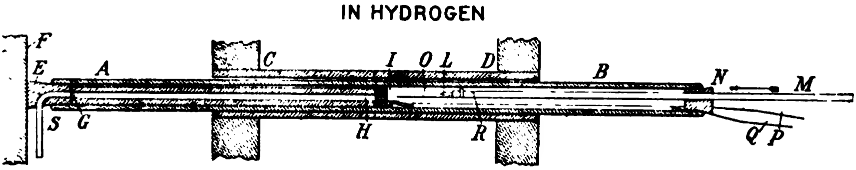

FIG. 7.—DEFORMATION-APPARATUS FOR USE IN HYDROGEN.

pended from *B* so that, taking into consideration the length of the arms of the lever, a desired pressure is brought on *a*.

Between 200° and 400° C. the ordinary needle would lose its hardness; so it is replaced by a needle made of high-speed steel.

Above 400° C. it is no longer possible to work in the open air; the oxidized film obliterates the silhouettes and the lines. The experiment must be made in hydrogen or nitrogen, and the needle made from cast quartz.

A porcelain tube, *A B* (Fig. 7), is heated along *C D* in a Mermet furnace. The extremity, *A*, is closed by a cork, *E*, which abuts against a wall, *F*. Another porcelain tube, *G H*, with an external diameter rather smaller than the internal diameter of *A B*, rests against the cork, *E*, at one end, while at the other end the specimen to be tested, *I*, is placed, along with two pieces, *K*, of the same metal, which press between them the end of a Le Chatelier couple.

The pieces, *I* and *K*, form together a cylinder which passes

into the tube without friction. The quartz needle, *L*, is set in an iron tube, *M*, passing with slight friction the cork on the right, *N*, and resting on a partition, *O*, of thin sheet-iron diametrically placed. The wires of the couple, *P*, *Q*, pass between the tube and the cork, *N*, and are separated from one another within the tube by a pipe-clay tube.

The holder of the needle serves also as the gas-inlet, and is perforated with a hole, *R*, for the purpose. To make a test, the apparatus is cleared out by means of pure dry hydrogen, entering at *R*, and passing out at the tube, *S*, which penetrates through the cork, *E*, and is bent at a right angle. When this is done, *S* is closed, because the play between the handle of the needle and the cork, *N*, is too great to insure a fast joint, and it is by this passage that the gas now escapes. The furnace is lighted, and the temperature raised very slowly to the desired degree. When this is attained the needle is pushed against the polished surface, *I*, and pressed against it. With a little practice the pressure is easily regulated, so as to obtain impressions that are neither too large nor too small.

The same set of apparatus could serve for nitrogen were it not that the difficulty of drying nitrogen is greater than in the case of hydrogen; because tubes of sodium, which give off hydrogen as a result of the decomposition of the water-vapor, are not available, and to keep a polished surface of iron intact the desiccation must be perfect. We have therefore modified the apparatus in the following manner:

Two similar iron tubes, *A* and *B* (Fig. 8), closed at the lower end, are placed upright side by side in a nickel crucible, *C*. The test-piece, *D*, is placed at the bottom of tube, *A*, and covered with a convex disk, *E*, of thin sheet-iron, with a small hole in the center, which supports the point of the needle, *F*. At the bottom of tube, *B*, there is a piece of iron, *G*, in which is inserted the end of a Le Chatelier couple, the wires from which, *H*, *I*, are separated from one another by a pipe-clay tube, and from the iron tube by a cylinder of mica. In making an experiment the crucible is filled with iron-turnings, which regulate the temperature, while *A* is filled up between the tube and the holder of the needle with iron which has been reduced by hydrogen at an incipient red heat; the whole is heated over a Méker burner until the desired temperature is attained. This

temperature is maintained, and the holder, K, of the needle is pressed. The pressure-figure is made, and there is nothing more to do but to let the test-piece, D, cool before removing it.

The iron should be reduced by hydrogen at a temperature sufficiently high for it not to be pyrophoric, and yet just as low as possible. It then serves to absorb the small quantity of oxygen retained at the bottom of the tube, and also any that may leak in during the progress of the operation. Its use was suggested to us by Mr. Lebeau, and it has succeeded perfectly. The compact iron is less prone to oxidation, and is protected by it. At first we tried copper, which is, in fact, protected by the iron; then we tried Goldschmidt manganese, which arrests the oxidation of iron quite well, but affects its surface, probably on account of the presence of impurities.

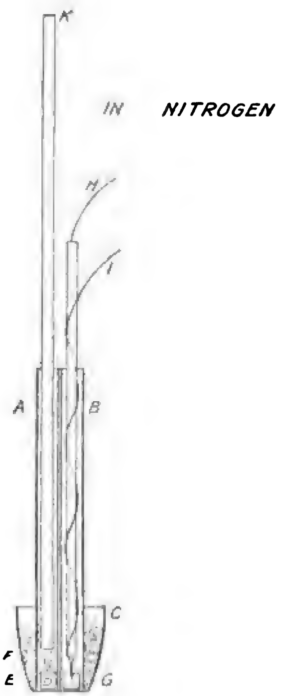

FIG. 8.—DEFORMATION-APPARATUS FOR USE IN NITROGEN.

According to circumstances, one or other of the three apparatus mentioned has been used.

On α-iron the indenting has been done at the temperature of liquid air, at the ordinary temperature, at blue temper, and at 600° C.

On β-iron at about 800° C.

On γ-iron at 900°, and when employing manganese or nickel steels, at the ordinary temperature.

In every case the silhouettes have the same form on the same crystallographic face, whether the iron was in the state α, the state β, or the γ-state.

On the cube face $p(001)$ it is a cross, of which the arms are parallel to the diagonals of the square, and which has four axes of symmetry parallel respectively to these diagonals and to the sides of the square.

On a rhombododecahedral face $b^1(011)$ the figure may still have four arms, but not rectangular. Most frequently these branches coalesce in pairs, and give a silhouette of two sheets

turned towards the faces of the cube which are perpendicular to the section under consideration. The figure has only two axes of symmetry, parallel respectively to the sides of the rectangle.

On an octahedral face $a^1(111)$ there is a figure with three lobes, of which the axes of symmetry are the heights (or bisections) of the equilateral triangle.

To represent these silhouettes, let us imagine a cleavage-cube which has been subject to the truncations b^1 and a^1, apply these truncations to the face of the cube, which they cut at

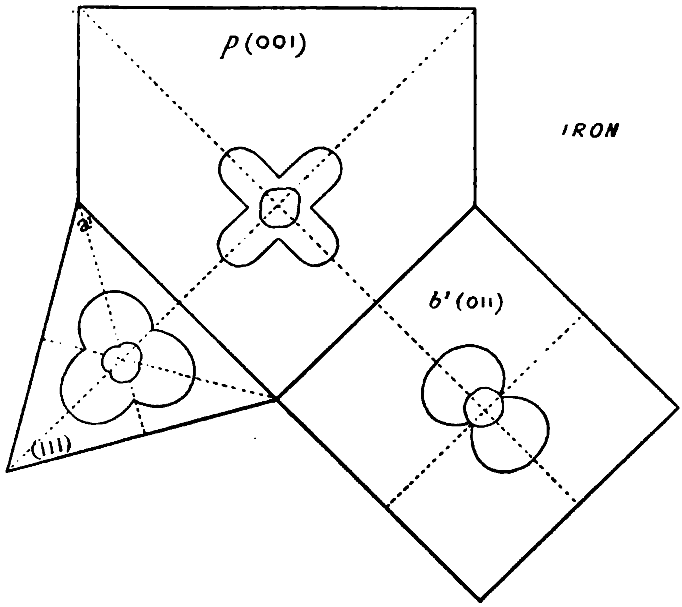

FIG. 9.—PRESSURE-FIGURES.

45°, and project the whole on the plan of the illustration. We shall thus have Fig. 9, upon which the silhouettes that we have just described are drawn.

These results confirm the conclusion that we have drawn from our previous trials—that is to say, that the three allotropic varieties of iron belong to the cubic system. In fact, this is the only system that can give figures with four axes of symmetry on three rectangular faces. The quadratic system could only have these on the bases $p(001)$ parallel with one another, and the cross, with four axes of symmetry, obtained fortuitously on one face, would not be repeated on an adjacent

rectangular face, as we have ascertained does happen. In the rhombohedric system the symmetry on one face $p(100)$ is, of course, very poor. Hence, with bismuth, which crystallizes in rhombohedra, simulting cubes, the pressure-figure on a polished natural face is that shown in Fig. 13 (75 diameters). There is only one axis of symmetry, parallel to one of the diagonals of the rhomb. Perpendicular to this axis there are the twin crystals or the lines of translation which have been described by Mr. Mügge.[9]

Of course our conclusions assume that iron remains in the γ-state from the point $A3$ up to fusion. Should it be demonstrated that the point of Ball and Curie, about 1,300°, corresponds to an allotropic transformation, it would be necessary to split γ-iron into two and to revise matters.

1 (*b*). *Discontinuous and Effaceable Deformation Figures.*

Every mode of deformation can be employed to produce these lines. But we have principally resorted to that which has already served us in obtaining the silhouettes described in the preceding section—that is to say, the normal pressure of a needle.

a-Iron.—The crystals are sliced from the cleavage-faces.

We shall first describe as typical the tests made at the ordinary temperature. The results are assembled in Fig. 10. The weight on the needle was 1.6 kilograms.

On face $p(001)$ the branches of the cross are formed of the folds $c\ d\ e\ f$, which envelop one another. The portions $c\ d$, $e\ f$ are nearly parallel to the diagonals of the square, and might be lines of translation; they are connected together by an approximately semicircular arc. Sometimes, from some unknown cause, this arc is replaced by a line, $g\ h$, which is comparatively straight and parallel to one diagonal of the square, and is connected by small arcs to the lines $h\ i$, $g\ f$.

On the truncation $b^1(011)$ the figure as a whole is still a cross, but its arms, $X\ X$, $Y\ Y$, are no longer rectangular. The acute angles, $XO\ Y$, are turned towards the intersection of the truncation with the face of the cube which is perpendicular to it. The arms are formed of the folds, $c\ d\ e$, roughly elliptical, and

[9] *Neues Jahrbuch für Mineralogie*, vol. i., p. 183 (1886).

enveloping one another. Almost always these folds, instead of closing up, coalesce on the bisection of the acute angles, either after inflection, as represented at *f g*, or without inflection, as at *k i h*. No straight line is visible.

On truncation $a^1(111)$, one can observe on each of the three axes of symmetry: firstly, nearly straight lines, *c d*, which are situated between the point of impact and a summit of the triangle, and parallel to the side opposed to this summit; secondly, curved lines, *e f*, which part at *e* from one of the axes of symmetry between the point of impact and the side of the

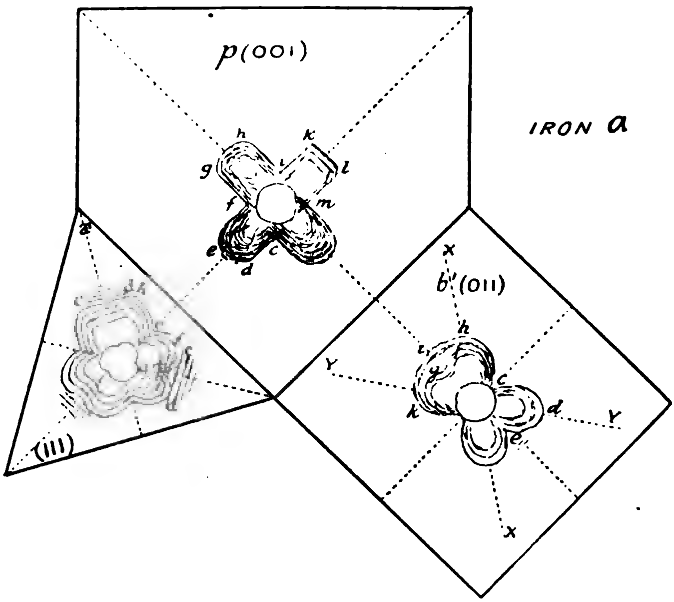

FIG. 10.—PRESSURE-FIGURES ON α-IRON.

triangle normal to the axis concerned. These lines, *e f*, have at their origin the aspect of spirals; they may bend, following *g f* towards the adjacent axis of symmetry, but more frequently they coalesce, as at *h*, with the straight lines *c d*, or again with their neighbors after inflection, as at *i*, or without inflection.

Other tests have been made on face *p*(001) at various temperatures. The silhouettes are the same in all cases, but the details may show some variation.

At the temperature of liquid air, under charges of 1.5 to 3 kg., the silhouettes are nearly without details.

At a blue temper heat there were produced many times one or more branches, such as *i k l m* (Fig. 10; face *p*)—that is to say, formed exclusively of straight lines; but these could not be reproduced at will.

At about 600° C. in hydrogen, the figure is the same as in the cold, but more subdued, and with little detail.

β-Iron.—It seems that at a red heat in hydrogen the polished iron surface suffers some modification, and that a superficial skin forms which masks the details of the deformation; even

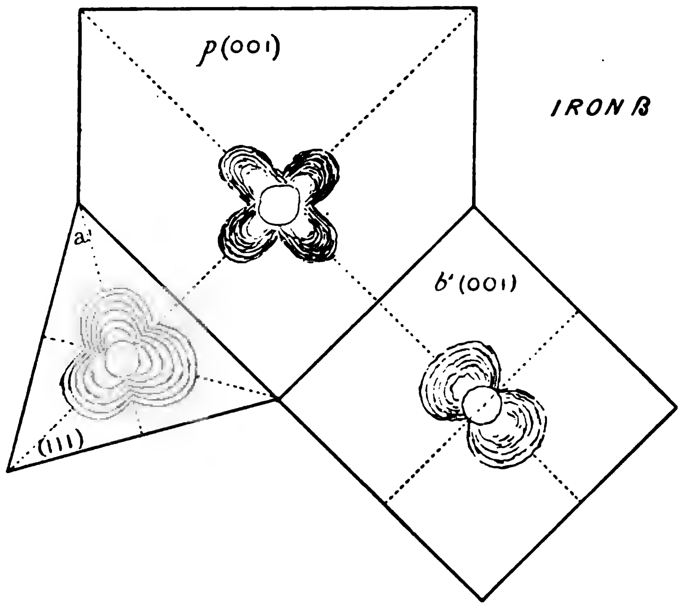

FIG. 11.—PRESSURE-FIGURES ON β-IRON.

after cooling, fresh indentings made at the ordinary temperature show nothing more than the silhouette. It is true that the details may be made to appear later on, either by spontaneous oxidation in the air (Fig. 14; 150 diameters; face *p*), or by etching with picric acid; but much sharper results are obtained by working in nitrogen with the apparatus (Fig. 8).

On face $p(001)$ the arms of the cross are exclusively formed of folds which cover or envelop one another; these folds appear to be generally more rounded than those of α-iron.

On face $b^1(011)$ the figure is the same as that for α-iron.

On face $a^1(111)$ the straight lines seen with α-iron are no

longer observed. The curved lines similar to the contours of the silhouette alone remain. See Fig. 11.

γ-Iron.—On face $p(001)$ the lines which cover the silhouette of the cross are straight, and parallel to the diagonals of the square.

On face $b^1(011)$ the lines are again straight, and belong to three systems—one is parallel to the intersection of the truncation with the face of the cube which is normal; the other two are symmetrical in relation to the sides of the rectangle, and make with one another, with a very gratifying approximation,

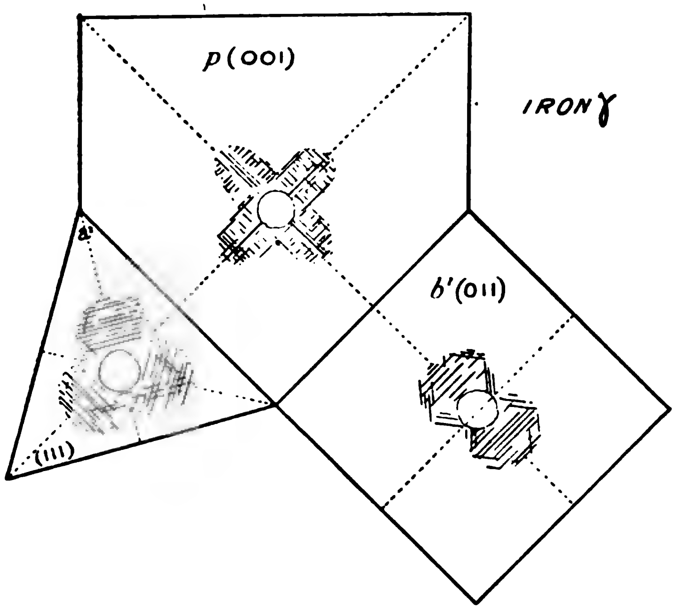

FIG. 12.—PRESSURE-FIGURES ON γ-IRON.

the theoretical angle of the faces of the octahedron—that is 109° 28′.

In face $a^1(111)$ the lines are always straight, and parallel respectively to the three sides of the equilateral triangle.

The results are arranged on Fig. 12.

We have also made deformation tests on practically pure iron above 900°. Under these conditions, we have seen a single crystal break up into grains; but under the condition of working in hydrogen, there are on these little grains lines of deformation; they are still straight lines—lines of translation.

The curved lines of β-iron and α-iron are therefore not attributable to a question of temperature. (We learn, subsequent to writing this note, that Mr. Rosenhain has made observations on γ-iron which agree with ours, and which were presented at the meeting of the Iron and Steel Institute in May.)

If we compare the three varieties of iron, we see at the start that the lines of deformation are exclusively straight on γ-iron. γ-iron, hence, has planes of easy translation, and according to directions noted, these planes are the planes

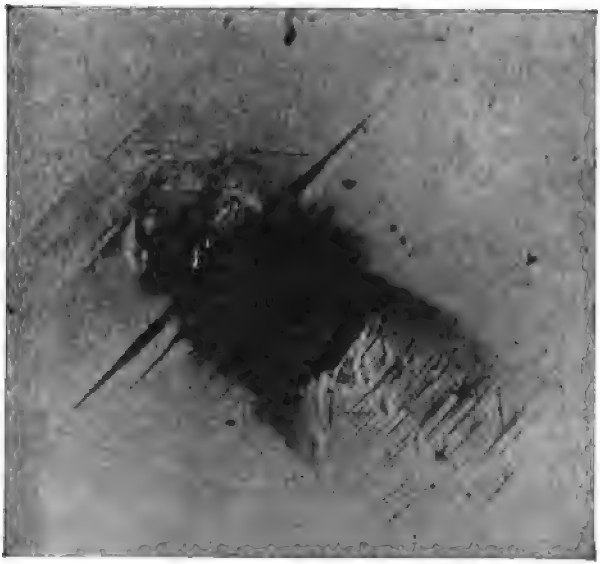

FIG. 13.—PRESSURE-FIGURE ON BISMUTH.

$a^1(111)$—that is to say, parallel to the faces of the octahedron, exactly as in the case of copper, gold, silver (Mügge), and lead (Humphrey).[10]

On β-iron the lines are exclusively curved; there are no planes of translation.

On α-iron there is, at least on faces p, and especially on faces a^1, a mixture of straight and curved lines. The orientation of the straight lines apparently proves the existence of planes of translation parallel with the faces of the octahedron—planes also referred to by Messrs. Ewing and Rosenhain,[11] and of

[10] *The Metallographist*, vol. vi., pp. 250 to 258 (1903). [11] *Loc. cit.*, p. 365.

which we had previously disputed the presence in iron. But the curved lines dominate considerably, therefore the translation is difficult, and the greater part of the deformation seems due to another mechanism.

We have employed on α-iron other modes of deformation—tensile tests, compression, bending—and in every case we have scarcely found anything but curved foldings, without any relation with the crystallographic directions either as a whole or in their details. We shall cite only one experiment, which appears to us convincing. We impressed the pressure-figures—that

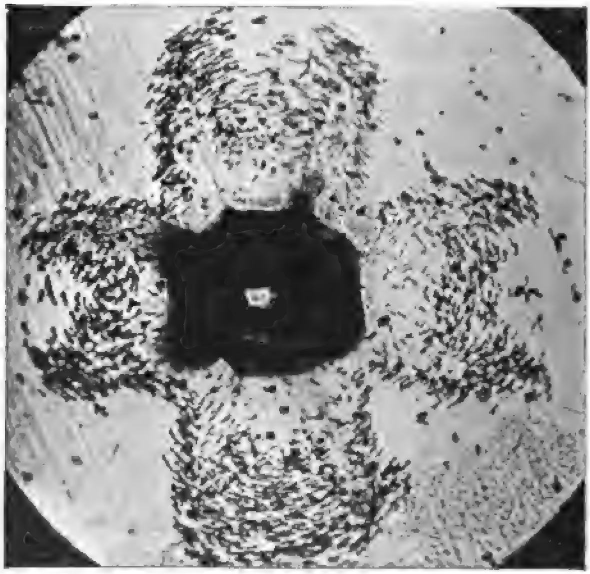

FIG. 14.—PRESSURE-FIGURE ON β-IRON AFTER OXIDATION.

is to say, the cross of Fig. 10—upon a crystal cut into an elongated rectangular rod, and presenting on two lateral faces the faces of the cube; the figures indicated immediately the crystalline orientation. Then we submitted the bar to gentle bending a little beyond the limit of elasticity. This new deformation produced new lines in the vicinity of the crosses, and on the crosses themselves; Fig. 15 (200 diameters) shows one of the crosses and its surroundings. It will be noticed that the lines produced by the bending are neither parallel to the diagonals of the square (axes of the arms of the cross) nor

to the sides of the square, as they ought to be, if they were the lines of translation following the faces of the octahedra or ot the cube.

1 (*c*). *Non-Effaceable Deformation Figures: Mechanical Twinning.*

The lines that have just engaged our attention, lines of translation or foldings, if obliterated by repolishing, do not reappear under the influence of etching. And, to our knowledge, slight static deformations produce no others.

FIG. 15.—LINES PRODUCED BY BENDING.

On the other hand, under certain circumstances that we are going to examine, lines are obtained that etching reveals after repolishing. These are actual lamellæ, with very slight but decided thickness; in other words, mechanical twin crystals or macles.

a-Iron.—The lamellæ known as Neumann's lamellæ or lines, in honor of the savant who discovered them in 1850, have been recognized for a long time in cubical meteoric iron and in kamacite (nickel ferrite). Their presence in terrestrial iron was noted by Prestel. (For the history of Neumann's

lines we have drawn, to a large extent, on the excellent book of Professor Cohen, *Meteoritenkunde*, Stuttgart, 1894.)

Neumann's lamellæ are visible frequently to the naked eye, on a cleavage-face. On these faces they are parallel either to the diagonals of the square or to the lines which join the angles at the center of the opposed edges (Fig. 16).

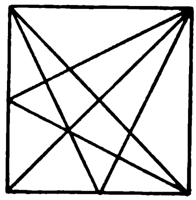

Fig. 16.—Neumann's Lamellæ.

After polishing to low relief, they appear as slight depressions on the faces of the cube, sometimes as depressions, sometimes in relief upon any other crystallographic section. The best reagents for showing that they have a decided thickness are alcoholic picric acid and nitric acid, the latter very dilute (1 in 500), which gently eats away the planes of junction (Figs. 17 and 18; 600 diameters). With reagents susceptible of giving corrosion figures, the interior of the lamellæ can assume a different color to that of the principal crystal which contains them.

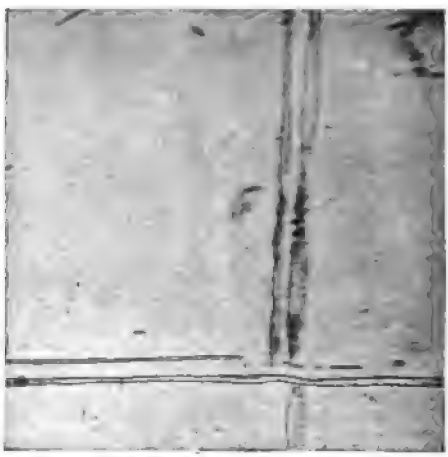

Fig. 17.—Neumann's Lamellæ after Etching.

The lamellæ may be of uniform thickness, like those to be seen parallel to the sides of Fig. 17, or present a more or less regular identation, probably connected with the formation of another system of lamellæ (Fig. 18). Fig. 19 (250 diameters; etched with picric acid) is a good example of indented or jagged lines on a non-oriented section.

If the etching is vigorous—for example, with 10 per cent. nitric acid for half a minute, after a previous etching for four minutes with double chloride of copper and ammonium to show the corrosion figures—Neumann's lines are then very much en

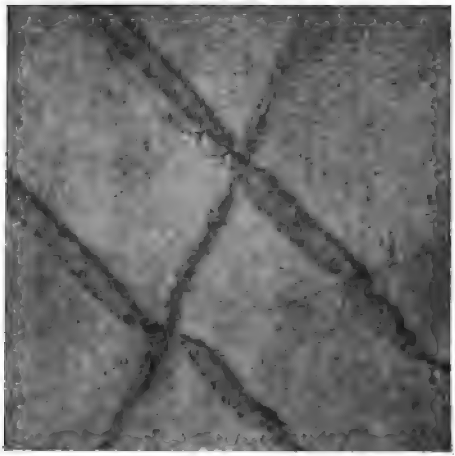

FIG. 18.—INDENTED LAMELLÆ.

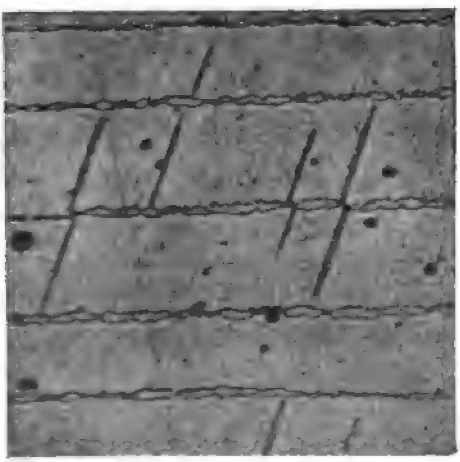

FIG. 19.—INDENTED LAMELLÆ.

larged; they become visible like so many fine file teeth, and if they are numerous enough, give the piece a watered aspect. Seen through the microscope, the line is channeled (Fig. 20; 250 diameters), but these channels, corrosion figures, markings

of strong etching, extend really to the edges of the lamellæ, and it becomes almost impossible to distinguish the lamella itself from the corrosion figures belonging to it.

Neumann's lamellæ have given rise to numerous works. It is agreed to regard them as twin crystals; but many divergent opinions have been expressed on the nature of these twins, on their position in the principal mass, and on the law of twinning.

Neumann[12] and, later, Tschermak[13] admit that it is a question of fluorspar twinning, which is represented (Fig. 21, 1*a* and 1*b*) in elevation and plan; the octahedral face is the plane of

FIG. 20.—PHOTOMICROGRAPH SHOWING CHANNELING.

twinning, and the ternary axis the axis of twinning. As there are four ternary axes, the lamellæ could belong to four cubic sub-elements imbricated in the dominant cube; and the twenty-four faces of these four sub-elements, identified with the planes of Neumann, would consequently be parallel respectively to the faces of the trioctahedron $a\frac{1}{2}$(122). Fig. 21, 1*c* indicates the position corresponding to a lamella on a diametrical plane passing through two edges of the dominant cube; the face of junction is the face of the cube of one of the sub-elements.

Rose,[14] who only studied the direction of etched lines,

[12] From Cohen.

[13] *Sitzungsberichte der Akad. d. Wiss. zu Wien, Math. Nat. Classe*, vol. lxx., p. 443 (1874).

[14] From Cohen.

could not decide whether the lamellæ are parallel to $a\frac{1}{2}(122)$ or to $a^2(112)$.

Sadebeck[15] has observed, on a cleavage-face of the dominant cube, that the faces terminal to those of the lamellæ, which make an angle of 45° with the sides of the square, make an angle of $144\frac{3}{4}°$ with the plane of the face of the cube. Regarding these terminal faces as the cleavages of the sub-ele-

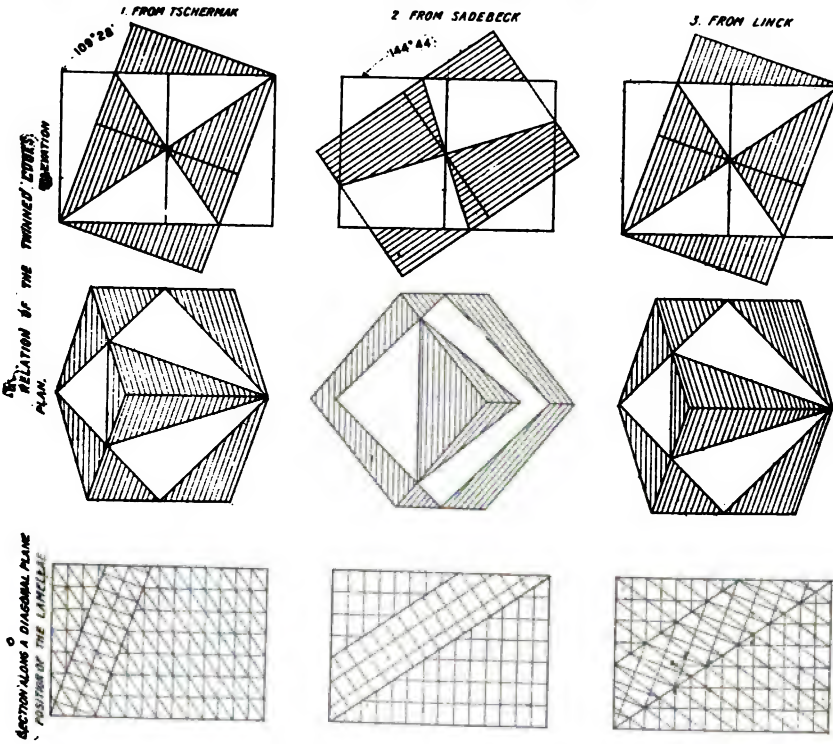

FIG. 21.—NEUMANN'S LAMELLÆ.

ments, he concluded that the plan of twinning belonged to a trioctahedron (20.20.9)—the axis of twinning being perpendicular to a face of this triocathedron. The law of association, represented by Figs. 21, 22, thus would become very simple; for in accordance with this law, and in the case of the two elements twinned, if one considers two faces of the twinned cubes cutting one another in the direction of a common diagonal, the face of one of these cubes is a face of the trapezohedron (112)

[15] *Poggendorff's Annalen*, vol. clvi., p. 554 (1875 .

of the other; moreover, in the same zone, an octahedral face of the dominant cube is the rhombododecahedral face of the secondary cube.

Finally, Linck[16] admits, with Neumann and Tschermak, the law of fluorspar twinning, but the junction faces should be $a^2(112)$ and not $a\frac{1}{2}(122)$. See Fig. 21, 3*c*. Under these conditions the planes of junction have the same notation for the two unit elements twinned. The planes $a^2(112)$ are at the same time planes of translation: the summit *d* of the mesh *a d b c* (Fig. 21, 3*c*) of the dominant cube has only to be transported at *d′*, parallel to *a b*, in order to form the twin.

In face of these different opinions, fresh researches would apparently not be useless.

Taking a trihedral cleavage-angle on Professor Tschernoff's iron, we cut a rectangular parallelopiped measuring about 15 by 15 by 7 mm., consisting mainly of a single crystal. We polished, etched, and photographed the six faces successively, and stuck the photographs on a wooden model of the size desired. The lamellæ of Neumann could in this way be followed on two or more faces; they were very numerous in the specimen, and it was certain that they were always parallel to the planes $a^2(112)$, which contradicts Tschermak's law of junction, and confirms that of Sadebeck and of Linck. The law of twinning still remained to be decided. It appeared difficult to decide experimentally between the two which have been proposed: Neumann's lamellæ are far too thin to permit of them taking pressure-figures; and for the same reason one would not fare better in attempting interpretable corrosion figures. But it may be remarked that Sadebeck's twin would be unique of its kind. The observation which suggests this—that is to say, the angle of 144¾° made by the fracture-facets of the lamellæ with the plane of cleavage of the dominant cube—is easily explained by Linck's conception: these fracture-facets are just simply the planes (112) of the lamellæ; and an experiment made on the

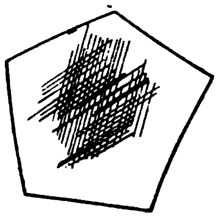

FIG. 22.—MECHANICAL TWINNING AND LINES OF TRANSLATION.

[16] *Zeitschrift für Krystallographie*, vol. xx., p. 209 (1892).

principal dominant cube shows actually that the planes of junction (112) of Neumann's lamellæ are also the possible planes of fracture. Therefore Linck's theory seems to us sufficiently demonstrated.

The question whether Neumann's lamellæ are congenital twin crystals, as Tschermak thought, or the result of mechanical twinning, in accordance with the common view of Sadebeck and Linck, remains to be decided. If we have to deal with congenital twinning, or a product formed during solidification, the twin crystals would really belong to γ-iron; but as we do not depart from the cubic system, the system would be maintained throughout the transformations, and a twin of γ-iron remain a twin of α-iron. There is, therefore, no objection on this head. But congenital twins are of the same magnitude as the crystals from which they are derived, since the development of the two elements twinned has been simultaneous. Neumann's lamellæ, on the contrary, are extremely small; moreover, as we have seen (Figs. 18 and 19), they are frequently inflected and thrust aside by meeting lamellæ of another system. Linck has also observed in the meteoric iron ot Braunau that the delicate lamellæ of rhabdite, $(Fe, Ni)_3P$, are broken and thrust aside by the lamellæ of Neumann; at least, it is easy to produce these lamellæ artificially by deforming, by shock, a fragment of crystal, of which the pre-existing lamellæ have been recorded by a photograph. Notably when a crystal of iron is cleaved, Neumann's lamellæ appear in abundance on both sides of the cleavage-face.

Therefore there is no doubt that Neumann's lamellæ are mechanical twins. Up to the present we have only been able to obtain them by shock, and more readily the lower the temperature. The Swedish iron that Mr. Hadfield ruptured by traction at the temperature of liquid air, exhibits many of them in the vicinity of the fracture.[17] At the ordinary temperature, the production of lamellæ is still easy, at least by shock, as we have already said. But it does not take place at the temperature of blue temper, nor at higher temperatures.

β-Iron.—In this case there are no known mechanical twins.

γ-Iron.—Slight deformation, without shock, only gives effaceable lines of translation. But more severe deformation fur-

[17] *Journal of the Iron and Steel Institute*, vol. lxvii., No. 1, p. 248.

nishes twins as well. On our nickel-chromium steel from Imphy we have impressed marks deeply in the cold; the surface marked in this manner was partly filed, repolished, and etched with a hydrochloric solution of iron perchloride. The etching shows, in the region of most deformation, parallel double lines, with the space between of different coloration to that of the grains in which they occur—this is therefore a question of twins. To determine the orientation, the etched piece was subjected to slight general deformation; lines of translation appeared, and it was always observed that one of the systems of lines was alongside or parallel with the twins

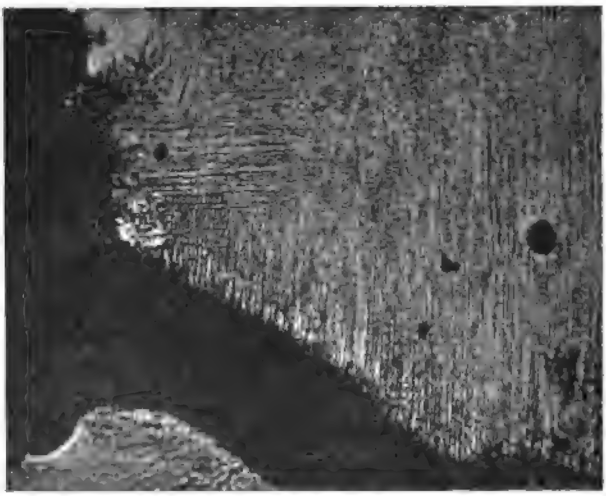

FIG. 23.—MECHANICAL TWINS IN MANGANESE STEEL.

If the twins are represented by heavy lines, and the lines of translation by fine ones, the scheme, Fig. 22, is obtained. The octahedral faces are, at the same time, planes of translation, planes of twinning, and planes of junction. The occurrence is frequent in the cubic system.

The same twins are obtained in manganese steel quenched at yellow heat, but they are localized around the lines of fracture, and are due to the tensile stresses which have caused these fractures (Fig. 23, of 200 diameters, and Fig. 24, of 800 diameters, etched with 5-per cent. alcoholic picric acid).

When the same metal is subjected to an alternative series of polishings and etchings, reliefs form around the patches of

cementite or other foreign substances which have not been dissolved, and on these reliefs the polishing alone results in the formation of twinned lamellæ (Fig. 25; 200 diameters; etched 30 seconds by a solution of ferric chloride, containing, per

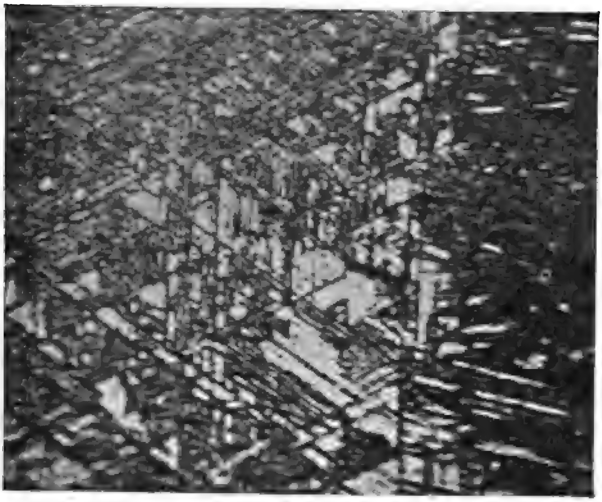

FIG. 24.—MECHANICAL TWINS IN MANGANESE STEEL.

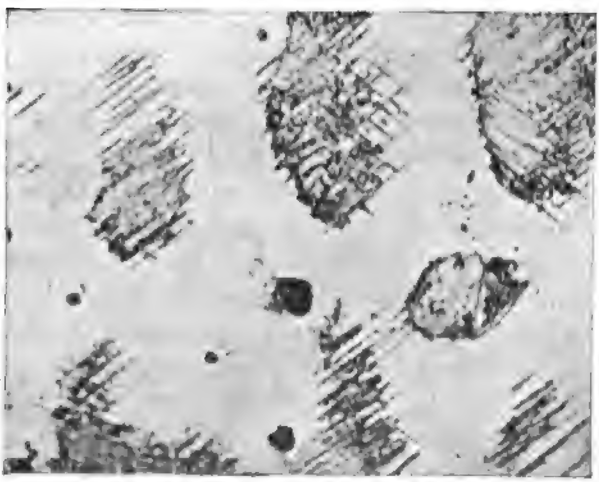

FIG. 25.—TWINNED LAMELLÆ IN MANGANESE STEEL.

cent., 10 parts of concentrated chloride and 6 of hydrochloric acid).

Figures 23, 24, and 25 recall martensite exactly, and thus offer an easy explanation of its structure: the partial transfor-

mation of γ-iron into α-iron, a transformation which starts below 400° C. in the case of sudden quenching, and causes considerable stresses. These stresses, in their turn, involve a more or less complete formation of an infinity of twins, parallel in each grain to the four pairs of octahedral faces; hence the frequence of square figures and equilateral triangles on a chance section.

The structure of martensite is hence a structure peculiar to γ-iron, although the iron is not present in the γ-state, at least for the most part. Even after tempering, when all the iron has resumed the α-state, if the temperature and duration have been sufficiently controlled to prevent the reconstitution of equiaxial grains which characterize α-iron, the α-iron may be retained pseudomorphic on the martensite structure of γ-iron. The grains are in this way cut up by an infinite number of extremely thin lamellæ parallel to four different planes; the continuity of the cleavages $p(001)$ is broken, and the natural fragility of α-iron, due to these cleavages, is evaded. Hence the part played by quenching and tempering in the amelioration of mild steels.

This structure of martensite is that of octahedral meteoric irons on a reduced scale. It is known that these irons are formed of comparatively thick lamellæ parallel to the four pairs of regular octahedral faces. Disregarding the tænite (alloy rich in nickel), the schreibersite, $(Fe, Ni)_3P$, and the plessite (mixture of tænite and kamacite), which may be found interspersed among the lamellæ, the latter are composed of α-iron containing about 7 per cent. of nickel in solid solution, and have received the petrographic name of kamacite (from καμαξ, beam). This is still a structure of γ-iron. Although the iron has resumed the α-state, this structure is preserved because, in the presence of nickel, the point of transformation A 3 is lowered to such an extent that the α-iron cannot resume its natural structure of equiaxial grains. The position is exactly that of martensite tempered at a moderate temperature. The α-iron remains crystallized on the axes of the γ-iron.

Linck was already convinced that he could affirm octahedral meteoric irons being polysynthetic aggregates of four twinned cubic sub-elements with a dominant cube, following the ordinary law: $a^1(111)$ plane of twinning and plane of junction. We

have tried to verify this affirmation on a fragment of a meteorite brought from the neighborhood of Timbuctoo by Mr. Ward. This fragment, taken from near the periphery, was unfortunately a little deformed. For this reason we have not been able to put Linck's law to the test by the study of Neumann's lines, on a section parallel to a face of the dominant cube. The directions observed differed too much from the theoretical to allow a verification of the law; but this difference would be explained by the notable deformations manifestly sustained, the least deformation causing the angles to vary rapidly. In fact, the method was too delicate in character. We then turned to a coarser and consequently more appropriate method, that of pressure-figures. If Linck's theory is true, a face $p(001)$ of the dominant cube cuts the associated four twinned secondary cubes on the planes $a^1(122)$. Every pressure-figure on such a face of the dominant cube ought then to be characteristic either of a plane (001) or of four planes (122) variously oriented, and no other figures ought to be formed. This is what experiment has fully confirmed, verifying again, in this instance, the conclusions to which Linck had been led by other methods.

Let us add that this polysynthetic structure is by no means peculiar to iron. There is a tendency for it to take place whenever allotropic or isomeric changes are produced in the solid state with a change in volume, so that the resulting tensions can effect mechanical twinning. It is in this manner that Mr. Breuil has been able to show martensitic structure in hardened aluminum bronze,[18] a fact which has been confirmed by Dr. Guillet.[19] These are only specific cases of a general phenomenon.

2. *Congenital Twinning.*

This can only be encountered in γ-iron, which alone crystallizes from the liquid state. But as we have said, in connection with octrahedral meteoric irons, these twins of γ-iron could, under favorable circumstances, be preserved in the α-state. It is in this way that Tschermak tried to explain Neumann's lamellæ. But this explanation, although it did not prove reliable in this particular case, is plausible in itself; and it may

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[18] *Comptes Rendus*, vol. cxl., p. 587.

[19] *Revue de Métallurgie*, Mem., vol. ii., pp. 567 to 588 (1905).

yet be asked if adjacent grains of a crude ingot of iron, each of which grains can represent a primitive crystallite or part of one, could not form twinned groups among themselves.

It is this that we have endeavored to investigate on the same crystal of iron of which we have already spoken, and which has served us in studying the crystallographical position of Neumann's lamellæ. The rectangular parallelopiped cut on three cleavage-faces contained, in fact, besides the dominant crystal, fragments of three or four adjacent grains. If a face $p(001)$ is etched by Heyn's reagent (12-per cent. double chloride

FIG. 26.—DOMINANT AND FOREIGN CRYSTALS.

of copper and ammonium) during 30 seconds, then by (1 to 5) nitric acid, to eat out Neumann's lines, the sections of the foreign grains viewed in vertical light have in general a much deeper tint than that of the faces $p(001)$ of the dominant cube. Moreover, on the latter themselves darker veinings can be seen. Fig. 26 (10 diameters), the sides of the photomicrograph are parallel with the sides of the face of the cube. When these veinings or marblings are studied it is seen that, as regards direction, they are related to the foreign grains. The micrograph reproduced furnishes an example: it shows seven dark bands slightly inclined to the vertical; the middle and longest

one is more pronounced than the others, and is not crossed by the Neumann's lines which meet it; this is a fragment of a foreign crystal, whereas the parallel bands crossed by Neu-

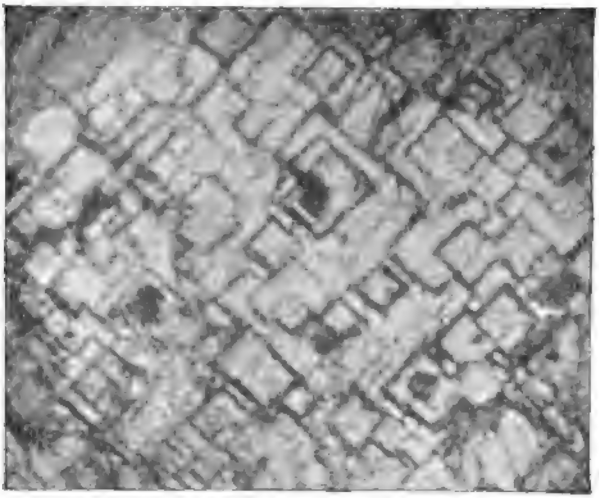

FIG. 27.—CORROSION FIGURES.

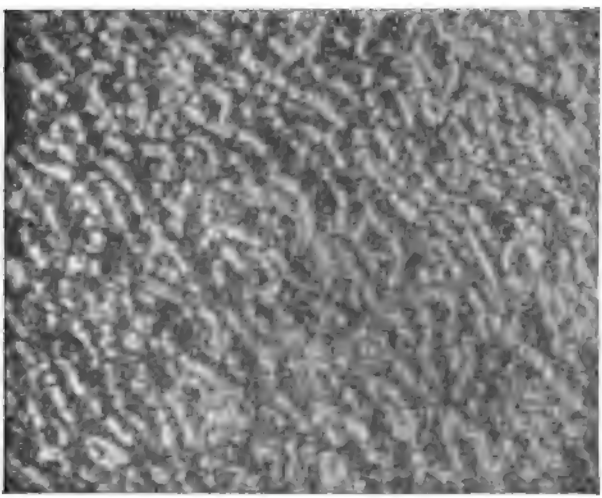

FIG. 28.—CRYSTALLITE BRANCHES.

mann's lines form integral parts ot the dominant crystal. Under high magnifications of the microscope, while the plain portions show beautiful square corrosion figures (Fig. 27; 1200

diameters), with the sides of the photomicrograph parallel with the diagonals of the square, the dark marblings show much smaller and less decided figures, separated by furrows strongly depressed, where, with the light and focus delicately adjusted, square forms can be recognized (Fig. 28; 1200 diameters). There is no doubt that these marblings represent crystallite branches which arise from one of the neighboring grains after solidification. These branches in course of a very slow cooling were assimilated below the point *A*3 by the crystal which they penetrate. Only, although the assimilation was crystallographically complete, since Neumann's lamellæ have nothing to do with the marblings, there yet remained some recognizable traces of the difference of origin, which are rendered evident by the copper chloride.

The grains that retained their own orientation different from that of the dominant crystal, are the residues of the primary crystallites. Therefore, from the actual orientation of the foreign grains we can see if these primary crystallites are formed in the position of twins. In that case, the face of the dominant cube will cut the twinned cubes on the planes $a\frac{1}{2}$(122), as happens in the octahedral meteoric irons. The experiment made with pressure figures only confirmed this conjecture for one grain in three. But the two other grains may originate from a different group; it would therefore be imprudent to draw a definite conclusion either one way or the other.

3. *Twinning Resulting from Annealing after Deformation.*

Such twins as these are produced with greatest ease in copper, bronze, brass, etc., as shown by the work of Prof. Heyn,[20] Mr. Charpy,[21] and others.

When a crystal of iron which has suffered partial deformation—by the pressure of a needle on a face of the cube, for example—is annealed either below *A*2 or between *A*2 and *A*3, the region of most deformation—that is to say, in the case under consideration, a ring round the point of impact—resolves itself into little grains of various crystalline orientation (Fig. 29; 60 diameters; etched with 5-per cent. alcoholic picric acid); but these new grains never show twinned lamellæ.

[20] *Zeitschrift des Vereines deutscher Ingenieure,* vol. xliv., pp. 433 to 441, 503 to 509 (1900).

[21] *Bulletin de la Société d'Encouragement* (5), vol. i., p. 180 (1896).

With γ-iron it is not the same. Our sample of nickel-chromium steel, which, as rough cast, contained no twin, developed a large number when cold-deformed and annealed at about 1,300°. It remained to determine these twins, although from our knowledge of meteoric irons it, *a priori*, was highly probable that we again had to do with a^1 twinning.

The grains were much too small, with a mean diameter of 1 mm., to permit of isolation and slicing, so a chance cut was made. It was probable that on this section, which contained a hundred or so grains, there would be some presenting spontaneously a cube face. To find them, the whole

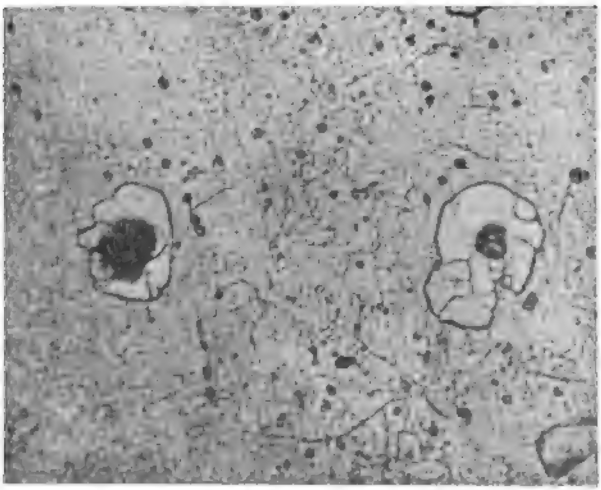

FIG. 29.—IRON ANNEALED AFTER DEFORMATION.

piece was subjected to slight general deformation in two directions at right angles, so as to show lines of translation in the polished section, and microscopic search was made for grains presenting two systems of rectangular lines and no others. We found one of sufficient size fulfilling these conditions (Fig. 30, above the line $A\,B$). This grain is cut precisely by lamellæ $A\,a\,q\,b$, $c\,d\,e\,f$, $g\,h\,o\,B$, $q\,p\,r\,s$, parallel to one of the systems of lines, without having the second: they are twins, and we happen to be on a face $p(001)$ of the dominant cube, or nearly so. To make certain, indentings were made with the needle, and the cross of the cubic faces was obtained in good form, and on one of the twins a different figure. However, on

looking closely into the matter, it was observed that the arms of the cross inclined slightly to the vertical lines; that the crosses gave rise to a new system of lines also slightly inclined to the vertical, and that the line *a b*, boundary of the twin that we have figured perpendicular at *A B*, is not exactly so. This was therefore not a true *p*(001) face, but it did not deviate much from one. To rectify matters, a cut was made perpen-

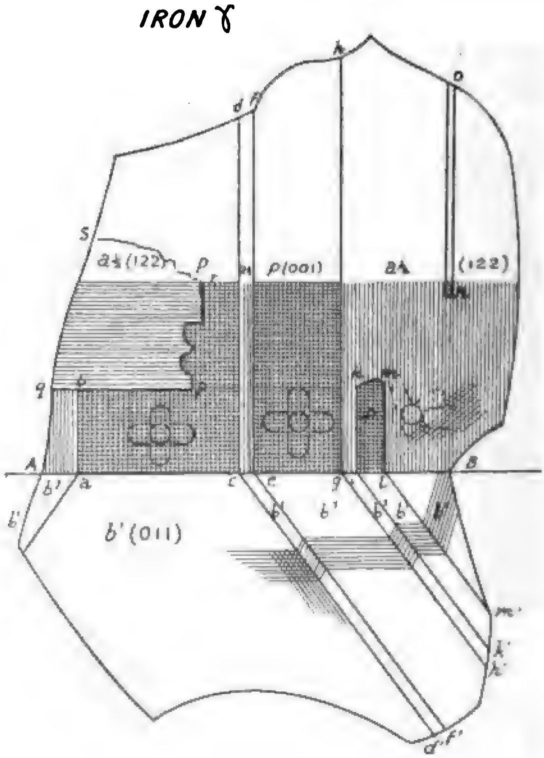

FIG. 30.—TWINS DEVELOPED BY COLD-DEFORMING AND ANNEALING.

dicular to the first following *A B*, and this is represented by the lower part of Fig. 30, after reduction to the plane of the picture. This section encounters the twins *A a b*, *c e d′ f′*, *g i h′ k′*, *l m′ B*, belonging to two different systems.

If it is a true b^1(011) face, and if our conjectures concerning the nature of the twinning are well founded, the lines *a* b^1, *c d′*, etc., should make an angle of 54° 44′ with *A B*. In reality, as may be supposed after the remarks made, these conditions were not well fulfilled. But taking the direction of the lamellæ

for a guide, the first cut was adjusted on a fine grindstone, then the second, and so on progressively. When the work was done, the two rectangular faces ought to be exactly $p(001)$ and $b^1(011)$ respectively; and the lamellæ ought to make with AB an angle of 90° on the first and of 54° 44′ on the second. From measurements made on the photographs with a protractor, the angles are respectively 89° and 54½°, which is a satisfactory result, more particularly as the production of lines of translation necessitated a slight deformation. The twinning resulting from annealing γ-iron is then the same as the mechanical twinning, with $a(111)$ for plane of twinning and plane of junction; it is possible, as we have already said, that the annealing simply develops the germs of mechanical twins.

4. *Mechanical Properties Functional of Crystalline Orientation.*

α-Iron.—Two prismatic test-pieces were taken in the same crystal previously annealed at about 800°, and cut in such a way that one of the axes of the figure was in the one case parallel to a quaternary axis of the crystal (lateral faces parallel to $p(001)$, $p(001)$, $b^1(011)$, $b^2(012)$); in the other case to a ternary axis (lateral faces parallel to $b^1(011)$ and $a^2(112)$).

These two test-pieces were submitted to compression, with the following results:

	Compression Parallel to	
	Quarternary Axis.	Ternary Axis.
Original height of prism in millimeters	11.22	8.905
Original section of prism in square millimeters	96.40	79.94
Limit of elasticity in kilograms per millimeter	13.9	17.0
Maximum charge in kilograms per square millimeter of original section	33.5	38.8
Final height in millimeters	10.48	8.34
Crushing, total in millimeters	0.74	0.565
Crushing, per cent. per kilogram above the elastic limit	0.34	0.29

Trials of hardness were also made by Brinell's method, under a charge of 140 kg., applied during 2 min. with a ball of 5 mm. diameter, with the following results:

Metal Annealed at Bright Cherry Red (about 800°).

	$p(001)$.	$b^1(011)$.	$a^1(111)$.
Diameter (D) in millimeters	1.642	1.602	1.533
$\pi D^2 : 4$ in square millimeters	2.1174	2.0157	1.8457
Hardness (H)	66	69	76

Metal Annealed at Very Dull Red (about 550°).

	$p(001)$.	$b^1(011)$	$a^1(111)$.
Diameter (D) in millimeters	1.540	1.500	1.484
$\pi D^2 : 4$ in square millimeters	1.8627	1.7672	1.7296
Hardness (H)	75	79	81

The number for the mean hardness of metal annealed at bright cherry red (70) is notably lower than the minimum (76) of Dr. Benedicks[22] for iron also annealed; this is explained by the absence of joints in our sample.

Each of our numbers is the mean of four impressions measured in two rectangular diameters. These impressions are neither so sharp nor so circular as on metals with fine grain, where they affect a large number of grains of varied orientation. Consequently there is some uncertainty in the measurement of the diameters, and as the differences appropriated to different faces do not much exceed the limit of experimental errors, the question may be asked if these differences are quite positive. We do not think, however, that doubt can be cast on them, since we have two simultaneous series concordant among themselves, with the compression tests and with the general law which assigns the minimum hardness to cleavage-faces.

The conclusions are that the mechanical properties of α-iron vary with the crystallographic orientation.

γ-Iron.—For this purpose Mr. Hadfield's manganese steel was used. The grains were sufficiently large to permit of test being made with the ball.

[22] *Thesis.* Upsala, 1904.

On face $p(001)$ the impressions are not circular: the diameters parallel to the diagonals are about 10 per cent. longer than the diameters parallel to the sides, by reason of swelling in the direction of the former. Means were taken.

On faces b^1 and a^1 the impressions are circular.

Under a charge of 200 kg., applied during 2 min. with a ball 5 mm. in diameter, the results were:

	$p(001)$.	$b^1(011)$.	$a^1(111)$.
Number of impressions......................	3	4	2
Diameter (D) in millimeters................	1.147	1.145	1.150
$\pi D^2 : 4$ in square millimeters..............	1.033	1.030	1.039
Hardness (H).................................	193	194	192

These numbers indicate a very moderate maximum of hardness on face $b^1(011)$, but the differences between different faces are less than those observed between two adjacent impressions on the same face. γ-iron is hence practically isotropic as far as the mechanical properties are concerned.

5. *Corrosion Figures.*

The corrosion figures of α-iron on face $p(001)$ have been described by Mr. Stead and Mr. Heyn. It is known that these are squares parallel to the edges of the cube face. We have given above a photograph (Fig. 27). On β-iron we have obtained corrosion or growth figures spontaneously in our previous tests on the crystallization of iron; they are the same as for α-iron.

On γ-iron, still working on face $p(001)$, the lines of corrosion are again parallel to the sides of the square. They are only neither so continuous nor so soft as on α-iron. As reagent, the double chloride of copper and ammonium, or 10 per cent. nitric acid, can be used for the manganese steel, while for nickel-chromium steel, iron perchloride, acidified with hydrochloric acid, is preferable: the etching is irregular, and, even after deformation, followed by annealing at 1,300°, shows the primary crystals very clearly. It is well to polish it lightly

again. The appearance Fig. 31 is then obtained, which corresponds to a magnification of about 200 diameters. The drawing shows a face $p(001)$ and an adjacent face $b^1(011)$, with a twinned lamella.

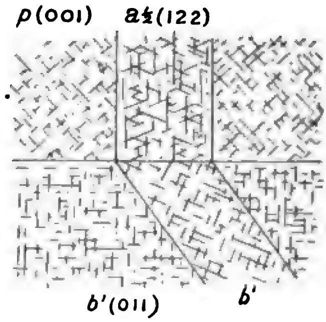

FIG. 31.—IRON CORROSION FIGURES.

To put it briefly, corrosion figures, up to the present, have not furnished useful distinctive characters.

6. *Synchronous Crystallization Figures.*

We heated to redness a crystal of iron having a cube face polished in a nickel crucible, beneath a layer of magnesia cal-

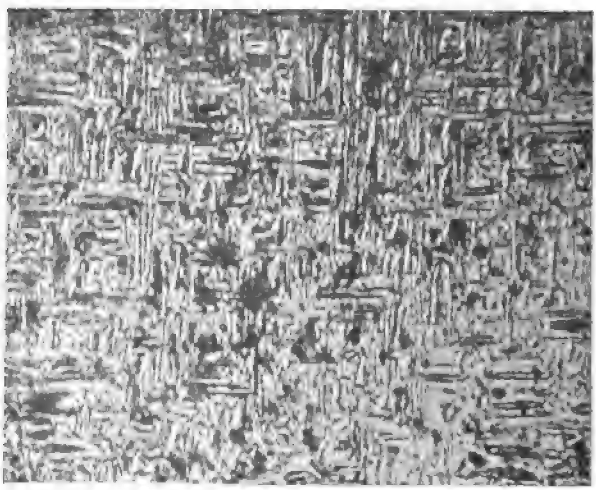

FIG. 32.—CRYSTALLIZATION FIGURES.

cined at a high temperature, which in its turn was covered with a layer of cast-iron shavings. The polished face oxidized naturally, and displayed square figures strongly resembling corro-

sion figures (Fig. 32; 400 diameters), the sides of the photomicrograph being parallel to the edges of the cube face. It seems that the oxidation has been regulated by the structure of

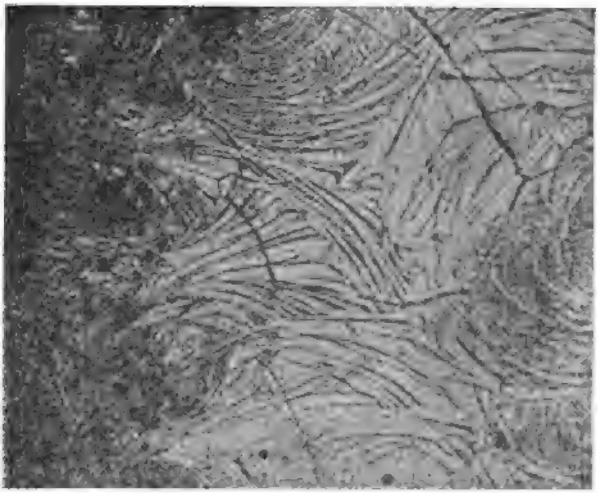

FIG. 33.—BORIC ACID MARKINGS.

FIG. 34.—BORIC ACID MARKINGS.

the metal. We have tried to repeat the experiment under known conditions of temperature, but without success.

In another test we introduced a crystal of iron, again having

a polished cube face, into a bath of molten boric acid, at about 800° C., the temperature being gauged by the eye. Needles of boric acid congealed at first on the polished surface, and preserved it provisionally from attack in such a way that the silhouette of the needles was imprinted on the iron (Fig. 33; 200 diameters). The interesting point is that the needles of boric acid, instead of arranging themselves on their own account in their natural order, as in Fig. 33, may follow the direction of the system of the iron; the appearance Fig. 34 (400 diameters) is then obtained, of which the sides are parallel to the edges of the cube face. In this some directions parallel to these edges may be seen, and others which seem to be parallel to the directions of Neumann's lines. These directions are really somewhat uncertain, because the needles of boric acid form fan-shaped groups, and, what is more, the experiment does not always take place in the way desired. Researches in this direction might, perhaps, merit resumption and following up.

7. *Segregation Figures.*

Crude cast manganese steel in the vicinity of the pressure presents details of structure that demand studying on their own account. Little hard nuclei are encountered, to which other constituents are attached, and notably lamellæ of cementite, crystallographically oriented.

On a cube face the nuclei occupy the summits of a square system. Fig. 35 shows the result of simple polishing at 65 diameters. The lamellæ which start from the nuclei, and others which are isolated in the metal, are parallel either to the edges of the cube face or to its diagonals, or to the lines which join the summits to the centers of the opposed edges. These lamellæ are too small to permit of their being followed on two adjacent cube faces: hence it is impossible, at least with the sample at our disposal, to determine exactly all the planes of segregation. Only it may be remarked that the lamellæ are of two kinds, and of decidedly different scales of magnitude, and that the larger ones are those which follow the diagonals of the square. It is concluded from this that the principal planes of segregation of γ-iron are again the planes $a^1(111)$; but that secondary planes also may exist $p(001)$, $b^1(011)$, $b^2(012)$, or $a\frac{1}{2}(122)$, among which we should not know now which to

choose. It is the lamellæ of cementite which contribute the relative brittleness to crude cast manganese steel, and cause it to break. The fracture then shows brilliant little facets disposed in cups; these are really the lamellæ. The quenching

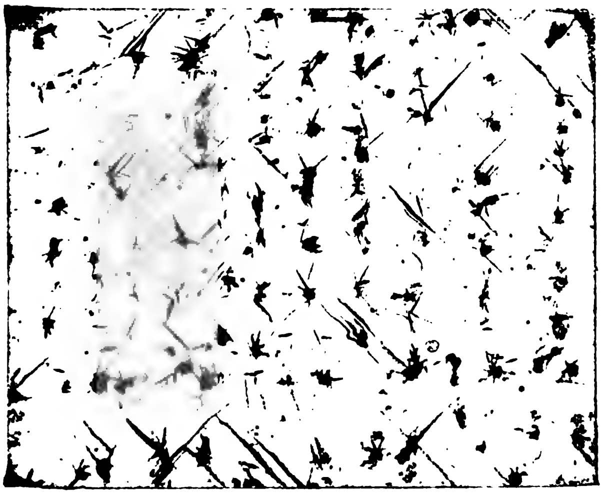

FIG. 35.—SEGREGATION FIGURES IN MANGANESE STEEL.

keeps the cementite in solid solution, and so communicates all the characters which distinguish the metal. In the same way, if hypereutectoid carbon steels are cooled from about 1,100° quickly enough, without actual hardening, the cementite is distributed in the planes of segregation of γ-iron.

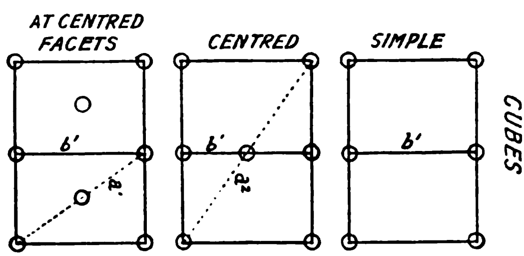

FIG. 36.—INTERSECTIONS OF CUBES.

Rose established that, in the cubic meteoric irons of Braunau and Seeläsgen, the rhabdite (Fe, Ni)$_3$ P is oriented in accordance with the three cube faces. Tschermak confirms this fact, and adds another possible plane of segregation parallel to

Neumann's lamellæ—that is to say $a^2(112)$. According to Kunz and Weinschenk, the rhabdite in the Floyd Mountain meteorite is parallel to Neumann's lamellæ. (All these notes relating to meteorites are borrowed from the frequently cited book of Cohen.)

Inasmuch as phosphorus tends to the elimination of point $A3$, it is possible that the planes of segregation $p(001)$ and $a^2(112)$ of rhabdite characterize either β- or α-iron. Systematic experiments on the crystallographic segregation of phosphorus, at known temperatures and on samples of known composition, would therefore probably be interesting. Mr. Stead, who has made such brilliant studies of the relations between iron and phosphorus, would be better fitted than any one else to conduct them successfully.

III. Summary.

The results of this research are set forth in the following table:

		α	β	γ
Planes of translation		$a^1(111)$ difficult	none known	$a^1(111)$ easy
Folds		dominant	exclusive	absent
Mechanical twinning	planes of twinning	$a^1(111)$	none known	$a^1(111)$
	planes of junction	$a^2(112)$		$a^1(111)$
Twinning by annealing	planes of twinning	none known	none known	$a^1(111)$
	planes of junction			$a^1(111)$
Face of maximum hardness		$a^1(111)$	?	$b^1(011)$?
Planes of easiest etching		$p(001)$	$p(001)$	$p(001)$

It is very difficult to interpret these results. Two courses suggest themselves.

Firstly, it may be supposed, with some probability, that the planes of translation, of twinning, of cleavage, and of segregation, are planes of the greatest reticular density, something like the walls and floors of a house. Moreover, it is known that there are three varieties of the cubic system: the simple cube, which only has intersections at its summits; the centered cube, which has another intersection at its center; and the cube with centered faces, with an intersection at the center of each of its faces. (These three cubes are represented by Fig. 36, projected on one of their diametrical planes; the little cir-

cles indicate the intersections.) In the simple cube the plane of the greatest reticular density is the plane $p(001)$, and among the truncations on the angles, the plane $a^1(111)$. In the centered cube the number of intersections is doubled on $b^1(011)$ and $a^2(112)$, and is not modified on $p(001)$ and $a^1(111)$, so that the reticular density becomes greater on b^1 than on p, greater on a^2 than on a^1. In the cube with centered faces the number of intersections is doubled on p and b^1, quadrupled on a^1, which becomes the plane of greatest reticular density. If it is now observed that p is a plane of perfect cleavage and minimum hardness for α-iron, and that a^1 plays the part, by far the most prominent part, in the crystallography of γ-iron, one is led to think that if the mesh of α-iron is a simple cube, and that of γ-iron a cube with centered faces, then that of β-iron would be a centered cube. As, on the other hand, the number of intersections is equal to that of the cube meshes for the simple cube, double for the centered cube, and quadruple for the cube with centered faces, each allotropic transformation of iron will be characterized by a division into halves of the molecular polyhedron with rising temperature. This is a very simple view.

However, the plane $a^2(112)$ has a greater reticular density than $a^1(111)$ in the centered cube, and not in the simple cube, hence the Neumann lamellæ, which demand $a^2(112)$ as plane of translation, could not be attributed to α-iron. And one is led to attribute them to β-iron, which should be formed temporarily under the influence of shock. This is no unreasonable supposition, and may also be arrived at by other considerations, notably by the experiments of Curie and of Morris on the laws of the appearance and disappearance of magnetism.[23]

Secondly, Mr. Wallerant considers the mechanical twinning as a proof of merosymmetry.[24] That is another course to follow.

Really these attempts at interpretation are probably premature in the present state of the crystallography, but they can be used as working hypotheses. The only positive conclusion that we can draw from these researches is, that the three allotropic varieties of iron, although they all crystallize in the

[23] *Metallographist*, vol. ii., pp. 169 to 186 (1899).

[24] *Bulletin de la Société française de Minéralogie*, July, 1904.

cubic system, present well-marked specific characters, and cannot have the same internal structure.

IV. Appendix.

Nickel.—Pressure-figures were made at a temperature above the disappearance of magnetism, on a polished surface of a sample of nickel, containing a little iron and manganese, and previously cold-deformed and annealed at a white-heat. These indentions may be made in the open air, nickel being much less prone to oxidation than iron. Around each point of impact, lines of translation—that is to say, straight ones—were obtained.

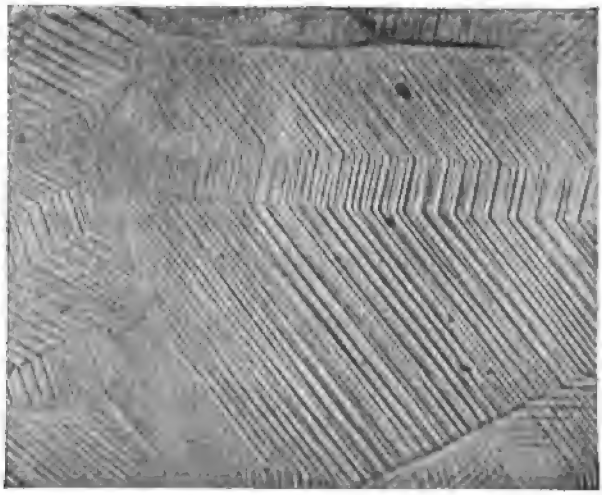

Fig. 37.—Pressure-Figures on Nickel.

Then, under the microscope, a new indention was made in the cold alongside each of the indentions made at the high temperature upon any grain with sufficient surface. In every case, the lines produced in the cold are also straight, and just like those produced on the same grain while hot. α-nickel and β-nickel have the same plane of translation, $a^1(111)$, which is also plane of twinning by annealing for β-nickel. It is true, as Professor Le Chatelier has said, that β-nickel corresponds to γ-iron; α-nickel corresponds to α-iron, with this difference, that it does not give curved lines of deformation.

We have also made deformation figures on the iron-nickel

alloy called "invar," of which the coefficient of dilatation is almost nil at the ordinary temperature, and which is in consequence in course of transformation at this temperature. It might be asked if this circumstance would not have some influence on the deformation lines. It has not any. Fig. 37 represents a section of this metal after slight deformation and previous polishings at 200 diameters. This section shows beautiful lines of translation. The twins seen were pre-existing. The deformation has only put them in evidence.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

The Application of Large Gas-Engines in the German Iron and Steel Industries.*

BY K. REINHARDT, DORTMUND, GERMANY.

(London Meeting, July, 1906.)

THE idea of burning blast-furnace gases directly in gas-engines, instead of under steam-boilers, as had previously been done, was first put into practice barely ten years ago, almost simultaneously in Great Britain, Germany and Belgium.

The pioneers of this movement made their first experiments with small engines. After these experiments had given satisfactory results, and it had been shown that the thermal value of the poor blast-furnace gases, in spite of defective scrubbing, could with safety be directly transformed into mechanical work in the gas-engine, there very soon arose a considerable demand for gas-engines of large power, similar to the large steam-engines employed in metallurgical works.

In face of these sudden requirements, the gas-engine builders were placed in a difficult position; for up to that time the gas-motor was considered as suitable for small engines only, and it was generally believed that the limit of size had been attained with 100 to 150 effective h.p. in a single cylinder.

Manufacturers of gas-motors, however, did not underrate the advantages offered by this new field for their manufactures, and it so happened that in Germany the Berlin-Anhaltische Maschinenbau-Gesellschaft, of Dessau, was the first to undertake the construction of a 600-h.p. two-cycle gas-engine, with two cylinders of the Oechelhäuser-Junkers type, for the Hoerder Mining & Smelting Company. The engine was started in 1898, and, with a few improvements and alterations, is still working satisfactorily. This engine worked with astonishingly high efficiency, considering the period. The builders were therefore

* Presented at the Joint Meeting of the Iron and Steel Institute and the American Institute of Mining Engineers, London, July, 1906, and here published under a mutual agreement between the Councils of the two Institutes.

in a position to prove in Germany that the gas-motor, even as a large engine, was suitable for the utilization of blast-furnace gases. The results obtained by the Hoerder Smelting Company, combined with the fact that the use of blast-furnace gases in gas-engines is much less dangerous than the burning of the same under steam-boilers, and is at the same time from three to four times as efficient,[1] encouraged other ironworks—*e.g.*, the Friedenshütte and the Differdingen—ironworks, similarly to introduce gas-engines; and during the last few years the example of these ironworks has been followed by a number of collieries, with a view to the more perfect utilization of the gases from their coke-ovens.

Even though, as was only natural, all these early gas-engines showed certain defects of design and insufficient purification of the gas, nevertheless, from the results obtained, and especially from those of the large installations of gas-engines supplied by the Cockerill Company of Seraing to Differdingen, it could be concluded that, with a small reserve, the power supply of an ironworks and, to a certain extent, of a rolling-mill, could be assured with gas-engines as the motive power, without serious disturbance of the existing arrangements. This can no longer be doubted when the improvements made by engineers engaged in the manufacture of gas-engines in their designs, as shown by the Oechelhäuser two-cycle motor, the Körting double-acting two-cycle motor, and the Deutz double-acting four-cycle motor, are considered. The Maschinenbau-Gesellschaft of Nürnberg, the Cockerill Society and other manufacturers have also entered the field. It would not otherwise have been possible for the application of blast-furnace gas to have become so widely spread in so short a space of time.

The present paper may be regarded as a continuation of those read before the Society of German Ironmasters by Dr. Lürmann,[2] Professor Meyer,[3] and myself.[4]

The object of the present paper is to review:

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[1] *Stahl und Eisen*, vol. xix., p. 484 (1899).

[2] *Ibid.*, vol. xviii., pp. 247 to 267 (1898); vol. xix., pp. 473 to 489 (1899); vol. xxi., pp. 433 to 459, 489 to 508 (1901).

[3] *Ibid.*, vol. xix., pp. 473 to 489 (1899); vol. xxv., pp. 67 to 72, 132 to 144 (1905).

[4] *Ibid.*, vol. xxii., pp. 1157 to 1182, 1352 to 1357 (1902).

(I.) The extent of the application of gas-engines in ironworks and collieries in Germany;

(II.) The working results, including the influence of purification on the gases; and

(III.) Present practice in the design of large gas-engines in Germany.

In order to arrive at conclusions as correct and complete as possible, the ironworks and collieries possessing gas-engines were invited to answer a series of questions, and the manufacturers of gas-engines to supply detailed drawings. And in taking this opportunity of thanking them, I wish to say that I received from all the ironworks and collieries complete and descriptive replies, which I was authorized to make use of, to my questions; the information received from the manufacturers being sufficient to enable the various types to be compared.

The questions, which were circulated through the kindness of the Society of German Ironmasters in February of this year, were as follows:

How many gas-engines have you at work, in course of erection, or on order? What type do they belong to? What size are they? What are they used to drive? What proportion of horse-power of the above are for continuous working, and how many are kept as reserve?

With what kind of gas are the engines worked—blast-furnace gas, coke-oven gas, or a mixture of both?

Is a gas-producer plant provided as a reserve?

How are the gases purified and cooled?

What power and how much water is employed for the purification of the gases consumed by the engine?

What proportion does this power bear to the power obtained from the purified gases?

What is the cost of purifying per cu. m. of gas?

What apparatus is employed to dry the gases after purification?

What is the percentage of dust contained in the gases before and after purification?

Are pressure-regulators arranged in the gas-main to the engines, and, if so, are they provided for each engine or for the whole installation?

What is the capacity of the pressure-regulator?

What is the pressure of the gases before they reach the engine, and within what limits does it vary?

At what temperature and with what percentage of moisture in grams per cu. m. is the gas supplied to the engines?

After what period of working is a complete cleaning of the internal parts of the whole apparatus undertaken, and how long does this take?

Which parts require cleaning first of all, or more frequently than the rest, and how long does the cleaning of these parts take?

Do stoppages and troubles occur, and what are the causes of these; (*a*) broken springs? (*b*) hanging of the valves? (*c*) failing to start? (*d*) failure of ignition?

Have important parts of the machine already become defective, and how long after the first starting of the engine? What do you consider the causes: (*a*) cylinders? (*b*) cylinder-covers? (*c*) pistons? (*d*) valve-boxes? (*e*) piston-rods?

How much water is used for cooling per horse-power and per hour: (*a*) for the cylinders? (*b*) for the pistons and rods?

At what pressure is the water used for cooling the pistons?

How much fresh oil is used per effective horse-power and per hour in the case of: (*a*) cylinder oil? (*b*) machine oil?

Has the consumption of gas by the engine been determined? If so, by what method, and what was it?

What sizes of units are, in your opinion, the most suitable for blowing-engines and for driving dynamos?

Can alternating-current dynamos driven by gas-engines be coupled in parallel without difficulty in your works?

A similar series of questions dealing with the special conditions at collieries was also sent out.

I. The Extent of the Application of Gas-Engines in Ironworks and Collieries in Germany.

I received answers to the questions in the beginning of March, 1906.

From the inquiry it was ascertained that of the 49 German smelting-works questioned, 32 had already gas-engines at work and 9 had ordered such engines.

		Horse-Power.
There were at work—	203 engines having a total effective power of about	184,000
In course of erection, erected, and on order,	146 engines having a total effective power of about	201,000
Together,	349 engines having a total effective power of about	385,000
	Of these engines there were:	
	64 having a power of about of older construction (single-acting four-cyle motors)	34,000
	88 engines having a power of about two-cycle motors, and	91,000
	197 engines having a power of about double-acting four-cycle motors.	260,000
	For driving blowing-engines there will be at work:	
	15 old form single-acting four-cycle motors of about	8,200
	44 two-cycle motors of about	50,100
	77 double-acting four-cycle motors of about	103,000
Together,	136 engines. Of about	161,300
	For driving dynamos there will be at work:	
	48 older model single-acting four-cycle motors of about	25,600
	41 two-cycle motors of about	35,700
	110 double-acting four-cycle motors of about	144,800
Together,	199 engines. Of about	206,100
	For driving rolling-mills there will be at work:	
	0 older model single-acting four-cycle motors,	0
	3 two-cycle motors of about	5,200
	7 double-acting four-cycle motors of about	10,900
Together,	10 engines. Of about	16,100
	For other purposes:	
	4 engines of about	1,500

There were ordered by German ironworks and collieries from March 1 up to July 1, 1906:

		Horse-Power.
	7 two-cycle motors of about	7,800
	24 double-acting four-cycle motors of about	28,350
Together,	31 engines of about	36,150
	Of these engines there will be working, for driving blowing-engines:	
	7 two-cycle motors of about	7,800
	7 double-acting four-cycle motors of about	9,400
Together,	14 engines of about	17,200

		Horse-Power.
	For driving dynamos:	
	0 two-cycle motors of about	0
	17 double-acting four-cycle motors of about .	18,950
Together, . . .	17 engines of about	18,950
	For driving rolling-mills:	
	0 engines of about	0
	For other purposes:	
	0 engines of about	0

The largest aggregate power of gas-engines at a single works amounts to 35,000 effective h.p.; 16 works possess over 10,000 h.p., and 27 works possess over 5,000 h.p. in actual working.

In most ironworks the whole of the gas-engines work continuously without any reserve; a few have up to 40-per cent. reserve of gas-engines, and a few have a similar reserve of older types of steam-engines or steam-turbines.

Nearly all engines in ironworks, naturally, work with blast-furnace gases. Two plants use only coke-oven gases, three use blast-furnace gas and coke-oven gas separately, and one plant uses the two gases mixed. Further, the Mansfeld Company utilizes the waste gases from the copper-smelting furnaces for driving gas-engines. Producers employing coke as fuel are kept as a reserve at seven works. They are really only of use in case of a strike, to assure the working of the most necessary part of the plant.

The application of gas-engines in collieries is much less important. This is due to the fact that the heat given off by the older type of coke-oven can only be utilized under steam-boilers, and consequently, for these older plants, steam-boilers are inevitable in collieries. Only the excess gas produced in the coke-ovens is available, so that steam-engines and gas-engines will always be found in conjunction, and indeed in larger proportion as regards steam-engines than is the case in ironworks. In the new regenerative coke-ovens the waste heat is utilized for pre-heating the oven itself, whereby there is an economy in gas, and a greater excess of gas is available for driving gas-motors. The irregular production of gas can, however, only be considered available or free from drawbacks for motor-driving when at least 60 coke-ovens are in operation. To this must be added, that the production of gas in coke-ovens is much more irregular than in blast-furnaces.

Perhaps in the near future, in addition to the excess coke-oven gases used for driving motors in collieries, producer-gas, which will be obtained in the ring-producer patented by Bergrat Jahns,[5] may also be used. The chief object of this producer is the utilization of the waste-heaps or culm-banks, and the production of gas as far as possible free from tar. The gas from the producer mentioned is naturally also suitable for the driving of gas-engines, which is demonstrated by the gas-engine plant at the Von der Heydt mine.

The same object is effected by the Turk and other producers; but, so far as I am at present aware, the utilization of the waste-heaps and of low-grade coal in gas-producers is only just being introduced, so that, for gas-engines in collieries, at present only coke-oven gas need be taken into consideration. So far as I am aware, in the beginning of March of this year, 16 collieries possessed 35 gas-engines at work, in course of erection, or on order.

The aggregate power of all these engines was 30,300 effective h.p. Of these, 24 engines were already working at 15,600 effective h.p., nearly all for the production of electricity.

The introduction of large gas-engines in collieries was subsequent to their introduction into ironworks, and, therefore, only engines of comparatively modern construction are to be found. Exception must, however, be made in respect to the smaller motors, which were early employed in plants for the recovery of the by-products in coke-oven gas.

II. Practical Experience Obtained in Working.

From what has been learned up to the present time it is clear that a thorough purification and drying of the gas is undoubtedly the principal factor in assuring a continuous and undisturbed working of gas-engines. German gas-engine manufacturers have from the very first considered the cleaning of the gas an essential condition, while, on the other hand, the Cockerill Company considered it unnecessary.

As a matter of fact, at many places Cockerill engines were working satisfactorily without any cleaning whatever, while at

[5] *Zeitschrift des Vereins deutscher Ingenieure,* vol. xlviii., p. 311 (1904).

other works this practice resulted in very disagreeable experiences; in one case, owing to the excessive wear of the working-surfaces of the cylinder, and another time owing to premature ignition caused by the formation of a crust, chiefly on the piston-ends, favored probably by excessive lubrication. If at one works the engines gave satisfaction without the gas being cleaned, and at another works similar engines were unsatisfactory, this only proves that the gas contains different percentages of dust at various works as it issues from the furnace-throat, and that it may become partly cleaned in the gas-main. It shows further that the same quantity of dust does not everywhere have the same effect, since it may be composed, in some works, of soft substances which do not so quickly cause excessive wear of the working-surfaces.

The design of the older Cockerill engines was, moreover, as regards the inlet-valves, not very sensitive to the effect of dust, the units most frequently constructed being 600 h.p. in one single-acting cylinder, and in consequence the sections of the gas-passages before the valve and of the inlet-valve itself were of rather large dimensions, and parts likely to be injured by the dust were not present with the system of governing then employed.

The methods of governing and of mixing the gases in newer constructions, in which stringent specifications for smaller variations of speed are laid down, are much more sensitive to the presence of dust, owing to their being combined with springs as delicate as possible, in order to keep the resistance of the governor and back-pressure upon it as low as possible.

If the spindles or regulating slide-valves are covered with a coating of dust, for instance, the springs are no longer sufficiently powerful to move these parts at all, or at the right moment, and in consequence disturbances in working result. This also occurs if dust is deposited on the valves or slides, the positions of which are regulated by the governor according to the load on the engine. The valves and throttle-valves (manipulated by hand) of the gas-main leading to the engine are also very sensitive to dust. The dust deposits on them very readily, and renders them difficult to move, and the areas at these places are for the time being unduly restricted, so that the engine does not receive sufficient gas to maintain

its normal power. In all the above cases, in addition to the percentage of dust, the percentage of water contained in the gas when admitted to the engine also exercises an injurious effect.

It is easily understood that moist dust adheres with greater facility to the surfaces with which it comes in contact than dry dust, the greater part of which passes through the engine without being deposited.

Great trouble is experienced with moist and dusty gas when the engine does not run continuously, but stops working on Sundays, for instance. It may then happen that the deposit of wet dust, which, while the engine is continuously working, does not offer very great resistance to the motion of the valve-gear, dries to a hard crust while the engine is not running, and causes these moving parts to become jammed, rendering the starting of the engine impossible.

The circumstances mentioned above are the result of the gas not being sufficiently purified or dried, as well as of the greater consumption of oil necessitated, and the consequent increase of dirt inside the motor, and, as a matter of fact, are the cause of most of the troubles experienced in working. For this reason, in all new plants, great importance is attached to the effective cleaning of the gas.

Before the introduction of blast-furnace gas-engines the washing of blast-furnace gas was considered necessary or advantageous for blast-heating and steam-raising purposes; the presence of dust diminished the efficiency of the combustion and of the heat-transmission, and rendered frequent cleaning of the hot-blast stoves necessary, although cleaning the gas for the above purposes did not have to be carried out to the degree necessary for the working of motors.

The whole of the gas from the blast-furnace is now subjected to a certain amount of washing, determined by experience, while the gas destined for utilization in the motors undergoes still further purification.

For a standard type of purifying plant for blast-furnace gas, the following may be observed:

The gases on leaving the blast-furnace are led through a series of so-called dry purifiers, and thence through long pipe-lines into the coolers or scrubbers, and from these into the

so-called centrifugal purifiers (Theisen apparatus or fans with water-spray). After leaving the above plant the purification of the gas should be complete, so that before being admitted into the engine the gas has only to be dried in filters or in capacious tanks.

In several plants, by drying and by passing through a long main to the engine, a further noteworthy purification of the gas takes place.

With regard to the construction and manner of working ot the various apparatus, the following remarks may be made:

The dry purifiers consist generally of a combination of cylin-

FIG. 1.—THE ZSCHOCKE SCRUBBER.

drical vessels, in which the gas is led downwards with a rapid motion and upwards with a slow motion. During this movement, and especially during the change of direction of the stream of gas, the coarsest particles of dust are separated. The pipes leading from the above should be made as long as possible, with as large a section and as many sudden changes of direction as possible, in order that the gas may be further freed from coarse particles of dust.

The coolers or scrubbers are vessels in which the gas flows from the bottom to the top and the water from the top to the bottom. The water must be finely sprayed in order to moisten

the dust, and thereby increase its weight and cause it to settle to the bottom. At the same time the gas is cooled in the scrubbers, in which the water-vapors are condensed and the dust is deposited.

The vessels are either empty, in which case the water is finely divided by spraying-nozzles, or the interior is arranged with sieves, wire-netting, coke, or wooden trays. The best example of the latter form is the Zschocke scrubber (Fig. 1).

The interior of the Zschocke scrubber consists of a series of wooden trays, one above the other, intended to reduce the velocity of the falling water, and by reason of their special form to divide the water into fine streams, so that the large surface exposed may effect a satisfactory cooling of the gas. The precipitated dust is removed at the bottom of the scrubber.

In centrifugal purifiers the further separation of the dust is effected by centrifugal action on the wet dust. The application of this apparatus renders it possible to attain a satisfactory purification of blast-furnace gas. The first centrifugal purifier in Germany was the Theisen apparatus, patented by Mr. Theisen of Munich.

In Duedelingen it was subsequently discovered accidentally that an ordinary fan, with water injection, was also very efficacious for gas-cleaning.[6]

The Theisen apparatus (Figs. 2, 3, 4, 5), according to a description given by one of the makers, the Dingler Maschinenfabrik, consists essentially of the following parts:

The suction-chamber, A.

The pressure-chamber, B.

The middle chamber, C.

The drum with shaft and bearings, D.

The grating, E.

Water enters at F tangentially to the casing of the middle chamber, C, and leaves the apparatus through the pipe, G.

The manner of working this apparatus may be described as follows:

After the gas has been cooled and charged with water-vapor, it is drawn in by the vanes, *h*, and the coarse dust is separated in the suction-chamber. Through the action of the fans at both ends of the drum, D, the gas is then drawn through the space

[6] *Stahl und Eisen*, vol. xxi., p. 447 (1901).

between the drum and the casing. The outer circumference of the drum (Figs. 2–5) is provided with a number of inclined spiral vanes, *i*, so that the gas has also to travel a long way in

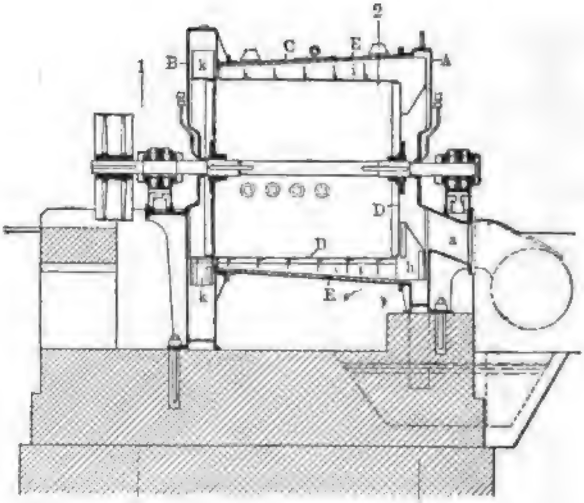

FIG. 2.—THE THEISEN GAS-CLEANER.

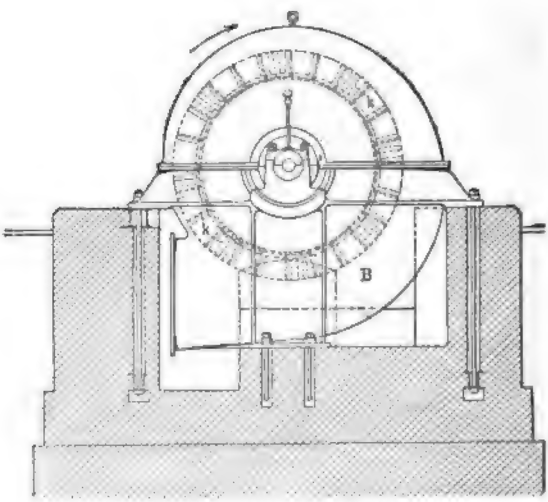

FIG. 3.—THE THEISEN GAS-CLEANER.

the form of a spiral. Hence, by injecting water at the same time through the pipes, F, a high degree of purification of the gas takes place, and the accompanying water-vapor is simulta-

neously condensed. The dust is then projected against the spiral meshes of the coarse grating, E, fixed to the interior surface of the casing. By centrifugal action, the water entering

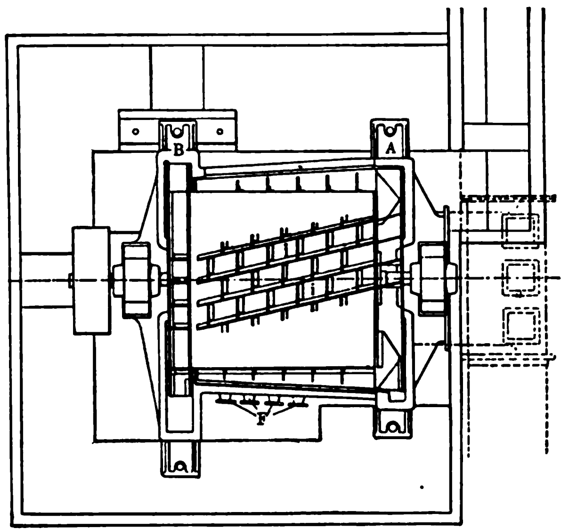

FIG. 4.—THE THEISEN GAS-CLEANER.

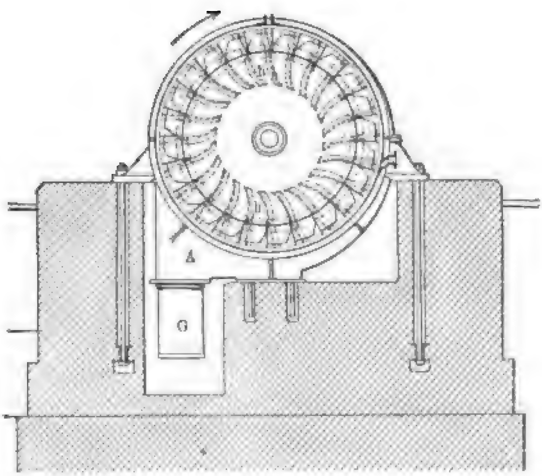

FIG. 5.—THE THEISEN GAS-CLEANER.

in a tangential direction is at the same time distributed over the surface of the grating, which prevents it from becoming clogged and incrusted with the separated dust. In addition to this, the surface of the water is broken up, thus favoring cooling and

condensation. This washing of the gas absorbs carbonic acid and sulphurous gases.

The purified gas then enters the discharge chamber, B, from which the water is thrown out by the vanes, *k*, and the gas is forced to the engines with a pressure of from 50 to 100 mm. of water. The washer reduces the dust from 3 or 4 g. per cu. m. of gas to 0.02 or 0.03 g., with a consumption of from 0.8 to 1.5 liters of water per cu. m. The washer is generally driven by a direct-coupled electromotor, and the smaller sizes by belting, at a speed of from 300 to 450 rev. per min. The sizes generally used range from 6,000 to 33,000 cu. m. per hr., and the power required from 50 to 150 effective horse-power.

Theisen imputes the useful action, during purification, in his washer to the steam present in the blast-furnace gas and to that formed by contact with the injected water, and on this account recommends his apparatus to be placed, not behind the scrubber, but without such apparatus, by introducing simple gas pre-moisteners immediately behind the dry purifier, in order that the gas may be as hot as possible at the entrance into the apparatus. On the other hand, Professor Osann,[7] in an exhaustive investigation of the purification of blast-furnace gases, chiefly by the action of cooling-surfaces for the water-vapors and the deposition of dust, considers it preferable to clean and cool the gases previous to their being introduced into the Theisen washer, so that the latter has only to remove the finer particles of dust which are otherwise difficult to separate. He hopes by this arrangement to effect a saving of power.

The fans employed for the purification of the gases, as constructed by R. W. Dinnendahl at Steele (Fig. 6), only differ from ordinary air fans in the construction of the vanes and bearings, which are of a much heavier construction, to cope with the injection of water and the higher temperature of the gas. They are provided with a water-inlet at the suction-opening, and with an arrangement, as in disintegrators, for pulverizing the water, so that a sort of water-curtain is formed through which the dust has to pass. The cohering particles of dust and water are separated by centrifugal action through which these particles are thrown against the inner circumfer-

[7] *Stahl und Eisen*, vol. xxii., p. 153 (1902).

ence of the fan-casing. The under portion of the fan-casing opens into a tank, A, from which the separated slimes flow away and the purified gas escapes at the top outlet. The method of purification resembles that of the Theisen apparatus, except that in the former the passage for the opposing action of the gas and water is not so long.

The usual sizes of gas-cleaning fans, according to Dinnendahl, are from 15,000 to 70,000 cu. m. of gas per hr., requiring from 40 to 110 h.p. The circumferential velocity of the im-

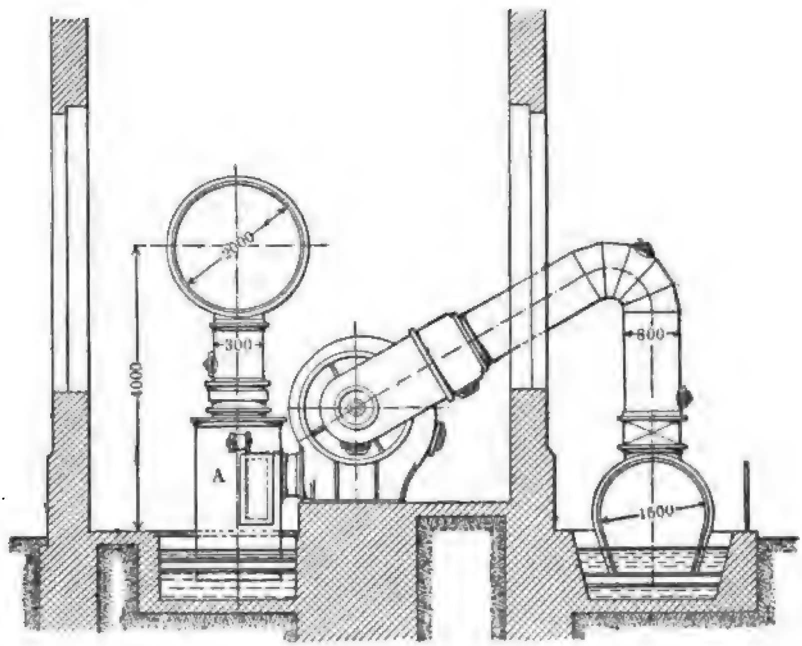

FIG. 6.—THE DINNENDAHL GAS-CLEANING APPARATUS.

pellers is up to 56 m. per second, with a diameter of from 1.1 to 1.75 m. For 1 cu. m. of gas from 1.5 to 2 liters of water are required, and the dust is reduced from 3 g. to 0.2 g.; as a rule, the percentage of dust is reduced to one-tenth of the percentage before washing.

When two or more fans are arranged parallel to one another for the purification of large quantities of gas, it is often difficult to obtain outputs equal in quantity and quality. It is therefore advisable to provide regulating dampers behind the fans, and,

above all, to make the mains, both before and after the branches to the fans, of large diameter, so that they can at the same time act as air-vessels. As a certain preventive of the above difficulties, which are often of a very annoying character, I can offer only one suggestion—namely, to drive the fans and the electromotors alike with the same speed in such a manner that their axes could be connected with friction-couplings, so that the fans produce equal differences of pressure.

Of the other purifying apparatus employed, only the Bian cooler may be mentioned.[8] This consists of a horizontal shaft turning within a cylindrical casing and carrying a number of disks of wire-netting. The lower halves of the disks dip into water, and the gas passes through the meshes of the upper halves. The purification of the gas is continued in centrifugal apparatus until the desired degree of cleanliness is attained, after which it has only to be dried. This is effected by forcing the gas through a series of layers of wood-fiber or wool in large cylindrical casings, to which it yields its water. Naturally, the resistance caused in passing through the layers of wool requires a large expenditure of power and the renewal of the wet wool, together with the cost of attendance, necessitates the installation of a spare drier. Large vessels containing various materials through which the stream of gas is forced, with frequent changes of direction, are employed for the separation of the water, and these vessels are further aided by long pipes with frequent changes of direction. If a large gas-holder is erected between the cleaning-plant and the engines, in addition to its quality as a pressure-regulator, it does excellent service in the separation of water, and renders the previous drying of the gas and the expenditure for attendance on the plant and power superfluous.

It must here be mentioned that in several ironworks it was not found possible to reduce the percentage of moisture in the gas arriving at the engine to the point of saturation at the corresponding temperature of gas. In such cases, after the supply of water to the scrubbers had been cut off, so that they were only employed as dry coolers or purifiers, the gas was not so perfectly cleaned, but was drier, and worked with less harmful results in the gas-motors than before.

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[8] *Stahl und Eisen*, xxv., —— (1905) (?); vol. xxvi., pp. 32, 465 (1906).

A few remarks concerning the purification of coke-oven gas for utilization in gas-engines must still be added.

The gas at disposal for this purpose has already been so far purified by the recovery of by-products that, as a rule, only the remains of tar, and also sulphur and cyanides, have to be removed. The tar-residues are removed in so-called tar-separators, which consist of high cylinders of boiler-plate in which a number of platforms or ledges are arranged alternately to the left and to the right, so that the gases pass through in a zigzag direction and the tar is deposited on the ledges. Other apparatus work in a similar manner, the main stream of gas being divided into a large number of smaller streams and by the resulting sudden alterations of direction, and also by impinging on the plate walls, the gas is freed from tar (Pelouze apparatus). Further, rotary cleaners are in use, which serve for the separation of ammonia, napthaline, cyanide, and hydrogen sulphide, and according to the form of the rotating surface are arranged as hurdle, brush, or ball washers (patented by Zschocke[9]). The Theisen washer can also serve this purpose; but, as far as I am aware, it has not as yet been so employed. The inventor hoped to obtain good results, especially in the separation of tar.

The separation of sulphur and cyanide is, according to Professor Baum, best obtained by filters. The filtering-material employed consists of Laming composition, a mixture of bog iron-ore and wood shavings. The composition, in layers of from 6 to 8 in. deep, is carried by plates or gratings; the gas passes through from two to four such layers, one after the other, and the iron combines with the sulphur to form iron sulphide, and with the cyanide to make iron cyanides (Prussian blue). The composition is from time to time taken out of the filter and exposed to the air, by which means the sulphur is oxidized and the composition regenerated and ready to be used again.

In passing through the filter not only the sulphur, but also the tarry liquors, water, and heavy oils remain behind. For this reason, plants which do not require the removal of sulphur often employ filtering-apparatus, the Laming composition being replaced by sawdust or wood-fiber. Gasometers, which are frequently placed as near as possible to the engines, and, as in

[9] Baum, *Glückauf*, vol. xl., p. 457 (1904).

the case of blast-furnace gas, at the same time regulate the pressure, also serve to dry the gas.

With reference to the purification and its influence, the following may be seen from the answers to the questions: All smelting-works have centrifugal apparatus in use for removing the fine dust, and, indeed, about half of them have scrubbers or Bian coolers with fans, and the rest scrubbers with Theisen apparatus, Theisen apparatus alone, or fans alone. The respective merits of the various apparatus or processes cannot well be ascertained from the information received from the ironworks, as it is not easy to reduce the results to a common basis. The following results nevertheless are perhaps of interest:

The power expended in cleaning 1,000 cu. m. of gas per hr. varies mostly between 6 and 13 effective h.p. Accordingly, the power expended in cleaning varies from 1.8 to 4 per cent. of the power obtained by the purified gas.

The amount of water used for cleaning varies greatly. It requires on an average from 3 to 8 liters per cu. m. of gas, and is naturally dependent on the temperature of the water. Generally speaking, the water used with centrifugal apparatus alone is less than when it is employed in combination with scrubbers. Similarly, the cost of cleaning varies considerably, and includes interest and depreciation of the purifying plant (from 0.03 to 0.06 pfennig per cu. m.).

The percentage of dust in the gas after the dry purification is on an average from 4 to 6 g. per cu. m. In a few cases, however, it is only from 1 to 1.5 g. In most instances the gas for working the motors is reduced to a percentage of from 0.015 to 0.03 g. of dust per cu. m., in a few works even to from 0.004 to 0.005 g. per cu. meter.

All these remarks concerning the percentage of dust are to be judged from the point of view that the determination of the same at one and the same ironworks, if not absolutely correct, will always be proportionately exact; but that this latter will perhaps not always be the case with tests carried out by different ironworks. It would therefore be of importance to adopt a standard method for the determination of the percentages of dust and water, so that all results could be exactly compared.

If the purification effected by the Theisen apparatus is compared with that by fans, it will be found that, according to the

manufacturers, the Theisen apparatus cleans in the proportion of 140 : 1. Thus, for 1,000 cu. m. of gas cleaned per hr. there is required 5 effective h.p. and per cu. m. 1.15 liters of water on an average.

With a fan the cleaning is on an average 10 : 1, the power required being 2.2 h.p., and the water used 1.75 liters.

In order to obtain a similar result, two to three fans would have to be placed one behind the other, which would require perhaps from 5 to 6 h.p. per 1,000 cu. m. of gas per hr., and a consumption of about 4 liters of water per cu. m. of gas.

From the information supplied by the ironworks only the total result can in most cases be reviewed; however, in a few cases the result of the cleaning by each apparatus is given, and from this I conclude that a single Theisen apparatus cleans better than a single fan, since with the former the proportion of cleaning is between 90 : 1 and 25 : 1, with about 6.5 effective h.p. per 1,000 cu. m. of gas, and with a fan the proportion is about 12 : 1 and the average effective h.p. 2.3. From two fans, one placed behind the other, a proportion of cleaning from 50 : 1 to 200 : 1 and power employed from 6.5 to 10 effective h.p. per 1,000 cu. m. per hr. has been attained. Without taking the consumption of water into consideration one Theisen apparatus is approximately equal to two fans.

With one exception, all ironworks possess apparatus for drying the gas as described above.

In no case does the gas contain any suspended water—that is, water above the quantity at the point of saturation at the corresponding temperature.

This temperature is in most cases the same as the temperature of the air, or only a few degrees higher. In a few cases the percentage of water is even lower than that corresponding to the point of saturation at the temperature of the gas, but this is only possible when the water used for cooling is at a very low temperature and the gas is cooled to below the temperature of the gas arriving at the end of the gas-main.

A further cooling of the gas would be of great utility, favoring the separation of water and purification, and thereby assuring the continual working of the gas-engines without disturbance.

The particulars which I have received from the collieries are

not so complete as those received from ironworks, owing to the collieries not yet having had so much experience.

Of 15 collieries which were questioned, two had no special plant for the purification of the gas, but only plant for the recovery of the by-products—four collieries have plant for the separation of sulphur and tar, six a similar plant for sulphur only, and three a plant for tar only. The power expended is only that necessary to overcome the resistance of the gas passing through the purifier, which is on an average about 0.25 per cent. of the power developed. The other working expenses consist only of the renewal of the filtering material, which amounts on an average to about 0.03 pfennig per cu. m., while the expenses of the purification-plant itself increase greatly with the sulphur in the gas.

Only traces of tar have to be removed by the purifier, but it is much more important to remove the sulphur, which attacks the cylinders, piston-rings, piston-rods, and stuffing-boxes.

In one case it is stated that the percentage of sulphur was reduced from 5 g. to 0.07 g. per cu. meter.

The heating-value of coke-oven gas varies from 2,500 to 4,600 calories per cu. meter.

The amount of gas available for gas-engines also varies extraordinarily, ranging from 3.25 to 50 per cent., according to the quality of the coal used, and above all according to the type of coke-oven.

In the replies to the questions addressed to ironworks, attention should be called to the fact that about one-half of the works place gas-holders between the purifying-plant and the motors. The capacity of the holders in proportion to the gas-consumption varies considerably. One ironworks places a gas-holder of smaller size, arranged as an equalizer of pressure, before each engine.

The pressure of the gas at the engines is on an average from 2 to 4 in., but in many plants it is 8 in. or over. The variations in the gas-pressure naturally depend on the number of gas-engines at work and of furnaces in blast, and on whether the blast-furnace tops are provided with a double seal or not. As a rule, it is recommended that the gas-pressure be maintained as regularly as possible, and not much above the pressure of the atmosphere (about equal to from 1.25 to 2.5 in. of

water). This can, of course, only be done by using a gas-holder, which, besides being an excellent separator for water, possesses the advantage of preventing a reduction of speed or even the stopping of the gas-engines when the supply of gas is suddenly interrupted for a short period, as may happen when only a small number of blast-furnaces are at work. Long gas-mains of large section also serve as a reserve, although not so effectively, and for a short period tend to equalize the pressure.

The intervals at which the engine or its several parts have to be cleaned vary greatly. From information received from ironworks, it may be concluded that with gas well cleaned (from 0.015 to 0.03 g. of dust per cu. m.), and at the same time well cooled and dried, the inlet-gear—that is, the parts before the cylinder of the engines—must be cleaned at intervals of two to three months, and a complete internal cleaning must be undertaken every six or eight months.

In a few plants using gas which is specially clean, the engines require less frequent cleaning. In others the inlet-gear, throttle-valves, and other similar parts require cleaning at periods of 14 days. At the same time, when the lubrication is not excessive, and even when the gas is not well cleaned, an internal cleaning of the engine every two to three months is sufficient.

The parts before the cylinder require for cleaning, on an average, from 6 to 20 hr., according to the size and build of the engine and the number of men employed, and the internal cleaning requires from two to eight days.

The quantity of water used for cooling the cylinders and pistons averages from 8.8 to 11 gal. per hr. and per effective h.p., of which from 2.2 to 2.6 gal. are for the pistons. The consumption of oil in most plants is reckoned at 1 to 1.25 g. per hr. per effective h.p. The consumption of gas has not yet been sufficiently tested to compare the various systems.

According to trials made at ironworks, the heat employed by the engines varies from 2,200 to 3,300 calories per hr. and per effective h.p. Most ironworks at present are not in a position to determine the consumption of gas in their engines, and content themselves with testing the exhaust-gases, and thereby determining the completeness of the combustion in the motor.

From the answers received from the collieries, engines using

coke-oven gas require cleaning after similar periods to those using blast-furnace gas.

Generally speaking, however, at present the collieries have not sufficient experience to answer this and other questions authoritatively. The traces of tar in coke-oven gas, which are difficult to remove and to burn, probably necessitate more frequent internal cleaning; and above all, the piston-rings, stuffing-boxes, oil-holes, and other similar parts require greater attention.

III. The Present Design of Large Gas-Engines in Germany.

From the answers received from the ironworks and collieries to the questions, it may further be concluded that the old arrangement of the single-acting four-cycle motor, with one or more cylinders, has not, in recent years, been generally used, and that, on the other hand, double-acting four-cycle motors, mostly with tandem cylinders, are in keen competition with two-cycle motors. There is therefore little necessity to deal in this paper with the obsolete single-acting four-cycle motors, which have been replaced by newer designs, particularly as many of these engines were only considered by their designers as of temporary construction, owing to the heavy demand which suddenly arose for large gas-engines. To this category belong the older engines of the Gasmotorenfabrik Deutz, of the Société Cockerill, of the Körting Brothers, and of the Maschinenbau-Gesellschaft Nürnberg.

Most of the new types which are now prevailing have already been described.[10] In order to institute an accurate comparison with the types since designed, it will be necessary here to recapitulate as concisely as possible the chief features of modern gas-engines.

Before commencing, the fact may be recalled that the possibility of making gas-engines of larger powers depended on overcoming the numerous prejudices and misconceptions of many gas-engine manufacturers. These were chiefly with reference to the idea that it was impossible to construct a stuffing-box, a cooled piston-rod, and a cooled piston, which should be reliable in working.

[10] *Stahl und Eisen*, vol. xxii., pp. 1157 to 1182, 1352 to 1357 (1902); vol. xxv., pp. 67 to 72, 132 to 144 (1905).

Once the possibility of constructing these parts to work in a reliable manner was proved by several engines built by Körting Brothers, John Cockerill, and the Maschinenbau-Gesellschaft Nürnberg, and after Körting Brothers had had a double-acting four-cycle engine running for a long time in their own works, and in the year 1902 made known their new double-acting two-cycle engine, a very rapid development took place. Many firms, which had previously built single-acting four-cycle engines, began to build double-acting closed cylinders and pistons working on both sides, so that in Germany at present, with the exception of the two-cycle Oechelhäuser motor, only the four-cycle Dingler engine has open cylinders.

To the best of my knowledge, at the present time 29 firms in Germany build large gas-engines. Of these, 21 firms build double-acting four-cycle engines, 5 firms build two-cycle engines, and 3 firms build both systems.

IV. General Remarks.

1. *Cylinder, Exhaust-Valve Chest.*

Until the year 1902 all German builders of gas-motors made their single-acting open four-cycle engines with cylinder ends, as used for small motors, the construction of which, owing to insufficient reliability, was the chief cause of the troubles encountered originally in the construction of large gas-engines.[11]

In the year 1902 the Gasmotorenfabrik Deutz[12] first introduced a design of cylinder (Fig. 7) which avoided the old cylinder ends, and was provided with an arrangement of lift-valves similar to a lift-valve steam-engine. The cylinder, which was provided with covers at both ends projecting within the cylinder in a similar manner to steam-engines, stood on a support in the center on which it could slide, and the outer mantle was, for part of its length, provided with an opening so that the semicircular turned support and semicircular cover at this place rendered the mantle water-tight. This manner of constructing the cylinder should avoid the danger of initial strains in casting, and reduce the stresses caused by heat in working,

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[11] *Stahl und Eisen*, vol. xxii., pp. 1157 to 1182 (1902). [12] *Ibid.*, Plate 20.

and also render possible the complete removal of the core after casting, and an easy cleaning of the cooling-mantle.

In examining the various designs, it will be seen that nearly all cylinders of the newer types of four-cycle engines follow the same principles as to the arrangement of the lift-valves. Most makers, however, consider that a separation of the outer casing is unnecessary, and that, for safety, it is more to the purpose to increase the height of the flanges, and thus provide a larger space between the inner and outer mantles. It is easy

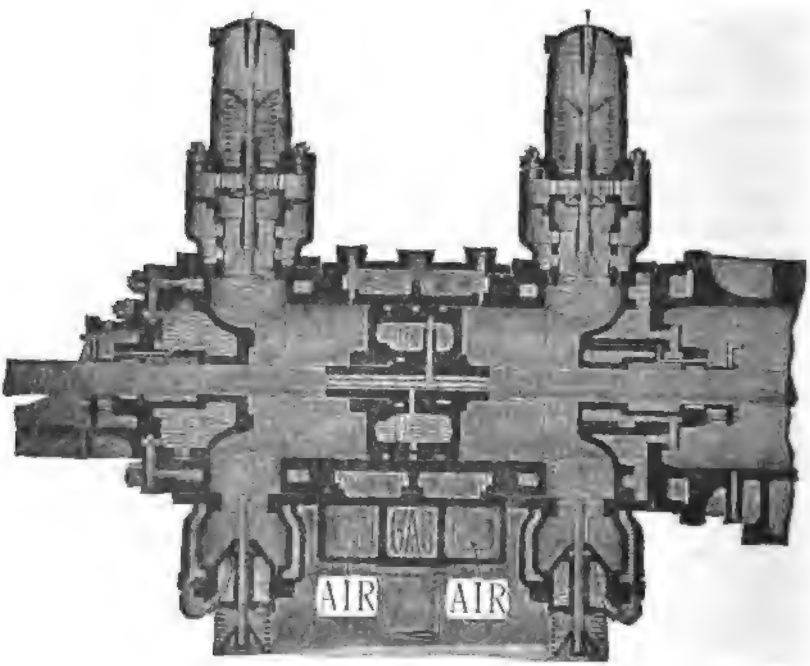


FIG. 7.—CYLINDER DESIGN OF GASMOTORENFABRIK DEUTZ.

to understand that a larger flange is better fitted to resist the stresses due to the difference of temperature between the inner and outer covers, owing to the definite rates of expansion distributed over a greater length. On this account calculations can only be made with approximate accuracy, because the average temperatures, and, in particular, that of the inner mantle, are unknown.

Compared with the older design of cylinder-heads, with a strong flange (with which both the outer and inner casings of the head were cast together, and bolted to the cylinder proper,

and with the outer and inner casings rigidly connected by the branches of the valve-chambers), the newer types offer without doubt far greater security against breakages.

In the older form of cylinder-heads, the stresses caused by the heat were always much higher, at the portion of the head between the branches for the valves and the flange, than they are in any part of the newest form of cylinders. In the first mentioned, the inner surface of the rigidly connected parts was exposed through the whole of their length to the highest temperature at each explosion, while modern cylinders are much better in this respect.

With the latter this can be explained by the fact that, because the cylinder-covers project into the cylinder at both ends as far as the surface of the joint, the inner cylinder-walls are cooled both from without and from within (by the cooled walls of the cylinder-covers), and further, that the middle portion of the inner walls, or rather the working-surfaces of the cylinder, do not generally reach these high temperatures, and the whole working-surface is passed over by a cooled piston.

In this manner the average temperature of the inner wall remains considerably lower than was the case with the older cylinder-heads, and the design is also much more trustworthy. Many makers have ceased to cast the valve-chambers, which, with the inner cylinder, form one piece, together with the outer mantle, and thus increase the security of the construction.

This is the reason why, during the last few years, few instances of cracked cylinders have been heard of, and in exceptional cases where they have occurred, those who have investigated the subject are agreed that the cause of the breakage had nothing to do with the construction, but was to be attributed to the presence of water in the cylinder, to the mantle being badly washed in the foundry, and to the formation of deposits, and such like causes.

The exhaust valve-chambers also belong to those portions of a gas-engine which, like the cylinders, cylinder-covers, and pistons, are exposed to dangerous stresses caused by the fluctuating temperatures of their walls, so far as the latter form a single casting. Their design requires for this reason considerable care, and, above all, a symmetrical form.

The construction of the exhaust valve-chamber of the engine

of the Maschinenbau-Gesellschaft Nürnberg is an improvement well adapted for its purpose (Fig. 8). It fulfils at the same time the condition that the inner portion, which carries the valve-seating, can be withdrawn downwards with the valve, without disconnecting the valve-chamber, or its connection with the exhaust-pipe.

Similar constructions are made by the Gasmotorenfabrik Deutz, by Ehrhardt & Sehmer, and other makers.

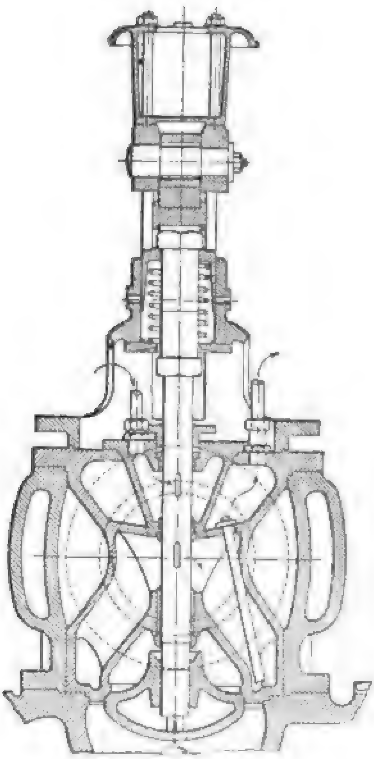


Fig. 8.—Exhaust Valve-Chamber on Engines of Maschinenbau-Gesellschaft Nürnberg.

With several designs it is impossible to take out the valves without unbolting the connections of the whole chamber, with the exhaust-pipe, and removing the latter; for instance the engines made by the Elsässiche Maschinenbau - Gesellschaft, and the Märkische Maschinenbau-Gesellschaft (Plates IV. and V.). An arrangement of the exhaust valve-chambers differing somewhat from other constructions is that of Schüchtermann & Kremer (Fig. 37).

This chamber, situated at the side of the cylinder, as seen in the figure, is so constructed that the walls are entirely protected from stresses caused by the variations of temperature. The valve with its spindle can in this case be withdrawn upwards.

I wish to point out that, in order to silence the exhaust, a spray of water is employed with advantage in the exhaust-pipe, and the exhaust-vessel is made as large as possible. In such cases the exhaust-pipe must be provided with a drain-pipe of sufficient dimensions to allow the water to flow off freely, so that in case of negligence in the use of the water-spray—for instance, at the starting of the engine—no water can enter the cylinder through the exhaust-valve, and thus occasion its destruction.

Now that the causes of the less important breakages of cylinder-covers and of pistons have been found to be partly due to a faulty arrangement of ribs, these difficulties should in future be overcome by experienced makers. These accidents are generally discovered in time, by a slight leakage of water, and consequently the failing of the ignition and the falling-off of the power of the engine. It is to be hoped that most of the designs of cylinders, cylinder-covers, and pistons of the newer engines will prove to be permanently trustworthy.

2. *Valve-Gear.*

Included in the valve-gear of gas-engines, in addition to the mechanism which is arranged for the regular motion of the principal inlet- and outlet-valves on the cylinder, for the admission of the mixture, and for the exhaust of the burnt gases, respectively, are chiefly to be reckoned those parts which serve to regulate the speed, through the influence of the governor and the formation of the mixture.

The inlet-valve is always cooled by the fresh mixture admitted; it therefore requires no special cooling. It is, however, absolutely necessary that the hollow exhaust-valves should be water-cooled. Water is circulated through the hollow valve spindle; at the same time it must be observed that the spindle must not be rendered water-tight by a stuffing-box, otherwise the valve easily hangs.

The valves are opened by an exterior mechanism driven by eccentrics or cams on a side shaft, which, in the case of four-cycle engines, runs at half the speed of the crank-shaft. The eccentric-rods in nearly all designs are combined with roller-levers.

Thus, in spite of the unavoidable acceleration of large masses of moving rods, and in spite of the pressure on the exhaust-valves when opened, the valves are lifted without shocks and the valve-gear works smoothly. The valves opening inwards are closed by springs.

The idea that cams are not suitable for operating lift-valve gearing is incorrect. A large number of gas-engines may be found working with valve-gearing controlled by cams, and the action of the latter is smooth and unobjectionable.

It is, of course, obvious that cams must be combined with

stronger springs than are necessary with eccentrics, because with the former, in addition to the valve, spindle, and roller-lever, the driving-rod of the gearing has also, as a rule, to be accelerated or moved by springs.

The strength of these springs, however, should not be greater than necessary with regard to the acceleration of the mass; but, for other reasons, *i.e.*, when the engine is working by quantity governing (and therefore with constant mixture and variable compression); and also if it is running without load, the springs must be of such a strength that they will prevent the opening of the valve to the partial vacuum formed at the time of the suction-stroke (which amounts to about one-fourth atmosphere absolute).

By the arrangement of a double-curved cam, provided with a roller and a counter-roller, a constrained motion of the rod may be obtained both for opening and closing by the roller-levers without the aid of spring closure, and by a suitable design of the valve-gear, the constrainment can be extended just as well with cam as with eccentric, even to the valve by the introduction of buffer-springs. The springs have thereby only to endure a compression of a few millimeters. This arrangement, as a rule, is applied only to the exhaust-valve motion.

With eccentric valve motions combined with roller-levers, the valve-rod and the active roller-lever always have to travel a long inactive distance, and therefore, as regards the admission-valve motion, usually require a long spring, having a compressive length equal to the travel of the valve.

In view of the satisfactory results of valve motions, whether controlled by cams or by eccentrics, no general decision can be taken as to which design is the better for all cases.

The most important thing is to give the cam the correct form to assure smooth running; and makers of gas engines, guided by experience, understand quite well how to do this, even though the method adopted is said not to be in accordance with the theory of the cam,

The valve-motions employed in large gas-engines for the purpose of governing and forming the mixture may be divided as follows:

(*a*) *The Quality Method of Governing, with constant total volume admission to the cylinder at each suction-stroke, and there-*

fore with constant compression, but supplying a variable mixture.—With this valve-gearing the composition of the mixture with a varying load is so varied through the actions of the governor, that (at a smaller power than the maximum) after opening the inlet-valve, air is first drawn into the cylinder and then at a certain position of the piston (depending on the momentary load on the engine and the position of the governor), the opening of the gas-valve commences, and the mixture continues to enter the cylinder until the end of the suction-stroke, when both the inlet and the gas-valve close.

Therefore, with a smaller load, more air and less gas, but, with a greater load, less air and more gas, are drawn in. The compression remains constant, but the composition of the mixture during the suction-stroke is not only very variable with a varying load, but also with a constant load. Seeing that at first pure air alone is admitted, and that it is only afterwards that the gas is drawn in, the air has acquired an accelerated motion in the inlet-pipe, while the gas, which is allowed to enter gradually, starts from rest and has to accelerate; and in addition the gas has to flow through an opening, the area of which is continually altering during the period of the opening of the gas-valve. The composition of the mixture alters constantly, owing to the opposing influence of the air- and gas-pressures, and to the alterations of the area of the gas-inlet, which occur during the opening of the gas-valve. The old gear, which is now rarely used, for operating the gas-valve by inclined notches, is somewhat upon the same principle. With the latter gear, the gas-valve was brought to the closing position at the end of the suction-stroke, and then the trouble arose that, through throttling the gas, a still poorer mixture ensued. After the compression this was located exactly in the neighborhood of the ignition.

To get over this difficulty the gas-valve was not allowed to close till after the dead center was reached—*i.e.*, until after the inlet-valve; and so long as the inlet-valve remained open, the gas was not much throttled.

The principal disadvantages of the latter are: the weak mixture; with low loads, and with the engine running light, the irregular ignition caused by this, especially with varying gas-pressure, and the resulting uncertainty of governing, as well

as a proportionately large consumption of gas with smaller loads.

The slow consumption of the weak mixture often results in the fact that the exhausting-gases, and those gases which remain behind in the cylinder at the beginning of the suction, continue to burn and thereby ignite the incoming mixture afterwards, owing to which back-firing occurs in the suction-passage, which unfavorably influences the governing and the regular working of the engine, especially when running without load.

A valve-gear, based upon the same principles, is at the

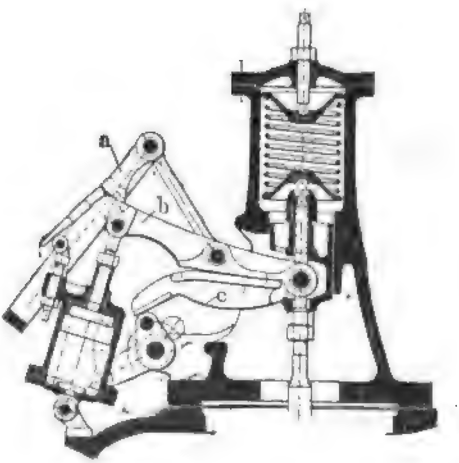


FIG. 9.—VALVE-GEAR OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

present time constructed by the Maschinenbau-Gesellschaft Nürnberg and their licensees (Figs. 9, 10).

The gas-valve is lifted by an active carrier, a, of a trip-gear jointed to an eccentric-rod and connected to an active roller-lever, b, which lies against a passive roller-lever, *c*, whose position is fixed by the governor. By this means the time of the opening of the gas-valve is dependent upon the position of the governor. When the carrier, a, is tripped, the gas-valve falls freely and closes at each charge, immediately with or shortly after the closing of the inlet-valve. This valve-gear—with the exception of the exterior mechanism, which is taken from

the modern steam-engine, and, moreover, is not free from a somewhat objectionable back-pressure on the governor—is in its action only an improvement on the inclined notch-gear.

The peculiarities of the quality method of governing described here induced the designer of the Nürnberg engine, Mr. Richter, to improve the valve-gear, with respect to the formation of the mixture, in the engines recently constructed under

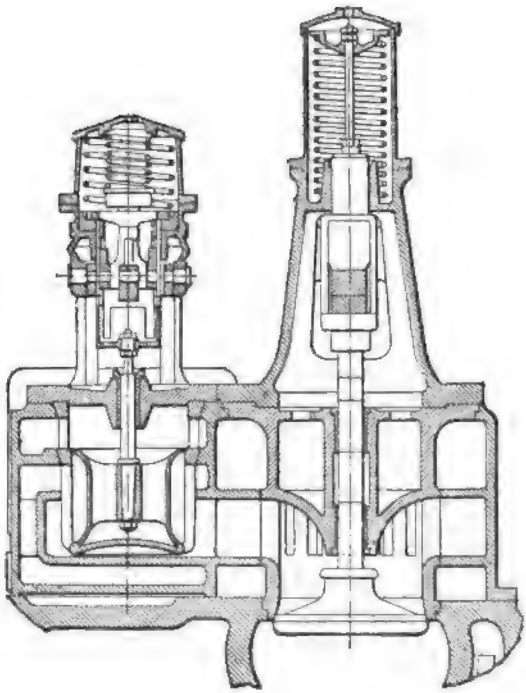


FIG. 10.—VALVE-GEAR OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

his direction for the firm of Thyssen & Co., Mülheim-Ruhr. As shown by Fig. 11, a balanced double-seated valve is combined with a sliding-sleeve on the same spindle, which, when the gas-valve is shut, permits the admission of pure air to the inlet-valve through a slit which is always open. If the gas-valve is lifted, the sliding-sleeve increases the area of the air passage regularly with the motion of the gas-valve. The object of this valve-gear is to obtain as regular an acceleration and retarda-

tion of the air- and gas-columns as possible, without the partial vacuum, induced by an early cut-off, being too high. Further, as the gas-valve is double-seated, a good distribution of air and gas is obtained, and at the same time the acceleration of the air-column is utilized to accelerate that of the gas-column.

It is necessary, first, to ascertain from experience whether

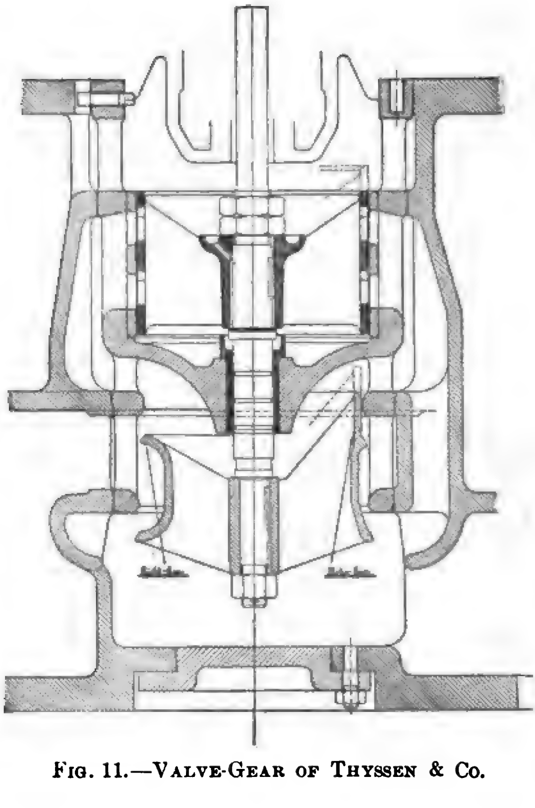


FIG. 11.—VALVE-GEAR OF THYSSEN & CO.

this formation is really an advantage, and whether this is not out-balanced by the higher vacuum produced in the cylinder during the suction-stroke.

Should this arrangement of mixing-valve, as opposed to the ordinary quality governing, not result in the anticipated advantage of a more regular mixture with constant pressure, I recommend that the air-slide be made to work in an inverted man-

ner, *i.e.*, in such a way that it opens to its farthest extent when the gas-valve is shut, so that, after the gas-valve has begun to lift, it reduces to some extent the area of the opening for the admission of air. By this means, also, the unfavorable influence of the air-column first accelerated would be lessened.

The disadvantages of so-called quality governing are naturally less considerable in engines which work mostly on a load which varies little from the normal load, such as for the driving of blowing-engines and pumps. But for even driving of these latter I consider the following method of quantity governing preferable to quality governing.

(*b*) *Quantity Method of Governing, with varying cut-off, and therefore varying compression, but with constant mixture.*—In this method of governing it does not happen that, after the inlet-valve is opened, first pure air and then a continually varying mixture flows in, but from the very beginning of the stroke gas and air are admitted, and always in the same proportion, so that the condition of constant mixture is fulfilled—*i.e.*, if the diffusion of this with the residual gases is not taken into consideration. It is clear that this valve-gear must give a more regular mixture at the normal power than the quality method of governing. For lower loads the amount of the constant mixture is diminished by the action of the governor, either by throttling throughout the whole length of the suction-stroke, as in the valve-gear of the Gasmotorenfabrik Deutz (Figs. 24, 25), or by closing earlier by a cut-off arrangement (either a valve or a slide), which enables the air and also gas to be admitted in the desired proportions from the beginning of the suction-stroke. This last arrangement of quantity governing requires a special drive for this regulating-valve from the valve-gear shaft, but to compensate for this the negative work with a small load is less during the period of suction than with throttling.

This manner of governing, according to Professor Meyer,[13] gives, even with the engine running unloaded, an almost perfect and regular combustion, from which follows the possibility of obtaining effective governing when the engine is running almost without any load. The consumption of gas with small loads is also more economical than with the quality method of

[13] *Stahl und Eisen*, vol. xxv., pp. 132 to 144 (1905).

governing, although, as compared to the consumption with larger loads, it increases, because the compression is reduced.

The advantages of this method of governing appear to be acknowledged by most of the older makers of gas-engines, with the exception of the Maschinenbau-Gesellschaft Nürnberg and their licensees. It is employed by Deutz, Cockerill, Körting, Elsässische Maschinenbau Actiengesellschaft, Ehrhardt & Sehmer, and others.

As regards the disadvantages of quantity governing, it may be stated that, owing to the reduced compression at small loads, the smooth running of the crank-gear is unfavorably influenced, and the partial vacuum formed in the cylinder, when the load is taken off the engine towards the end of the suction period, necessitates the use of very strong springs to load the valves in order to prevent them from re-opening and thus causing hammering and also prejudicing exact governing.

(c) *Combined Quantity and Quality Method of Governing.*—An example of a valve-gear of this kind is that of Mr. Reichenbach, constructed by the Maschinenbau A. G. Union, Essen, and by the Maschinenbau-Anstalt of Görlitz, in which, from the maximum power, down to a certain power, only the amount of the constant mixture is varied, while from this power, down to the power when the engine is running unloaded, proportionately more air is added; that is, the mixture is weakened, in order not to allow the compression to fall too much when running without load. In order to assure the ignition and combustion of the weaker mixture, at low powers, Reichenbach allows, with small loads, the moment of ignition to be so regulated by the governor, that the ignition, from the beginning of the weakening of the mixture, with a diminishing load, takes place earlier.

By this valve-gear, which will certainly prove effective, the air as well as the gas, each separately, then the mixture formed, and finally the ignition, should all be controlled by one or more governors.

(d) *Governing with a Constant Mixture and Constant Compression.*—A governor working in this manner has been patented by me and constructed by Schüchtermann & Kremer (Fig. 12). It was constructed in answer to a demand by Professor Meyer[14]

[14] *Stahl und Eisen*, vol. xxv., pp. 132 to 144 (1905).

for a method of arranging the mixture which, at constant compression, and with increasing quantity of air, renders complete

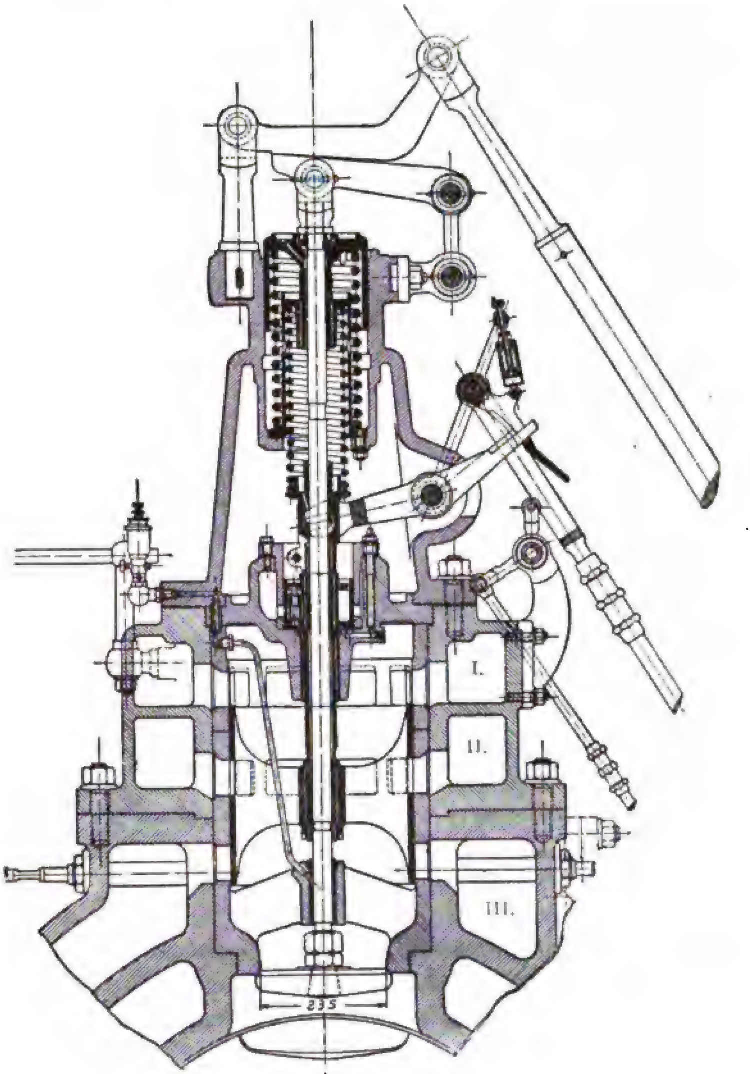


FIG. 12.—REINHARDT'S GOVERNOR USED BY SCHÜCHTERMANN & KREMER.

combustion possible, even when the engine is running without load.

The disposition of this governor consists therein, that two separate air-ports and a gas-port leads into the cylindrical space above the inlet-valve.

The inlet-valve opens at the commencement of, and closes at the end of, the suction-stroke. In the cylindrical chamber above the inlet-valve, and independently of it, a slide moves in such a manner that it first keeps the gas-port (I.), and then one of the air-ports (II.) shut, while it allows the admission of pure air through the air-port (III.), until, at a position of the piston depending on the load at that moment, influenced by the governor, it is suddenly disconnected from its outer mechanism, and through its resulting rapid downward motion, suddenly closes the air-port (III.), at the same time, however, opening the air-port (II.) and the gas-port (I.), so that both air and gas enter for the mixture, both from rest, and through areas which are of correct proportions. Only after the inlet-valve is closed does the slide again move upwards.

3. *Stuffing-Boxes, Cooled Pistons, and Piston-Rods.*

These important parts of large double-acting motors offer at the present time less difficulties than could ever have been expected.

There are stuffing-boxes of various constructions in use, all of which give satisfaction, and the following packings may be cited as examples: Sieger (Fig. 13), Maschinenbau-Gesellschaft Nürnberg (Fig. 14), Elsässische Maschinenbau-Gesellschaft (Fig. 15).

The construction of these packings can be clearly seen from the figures, and requires no special description.

With several packings all the rings are made of cast-iron. In a few types only those rings situated nearest to the explosion-chamber are of cast-iron, while the remaining rings are made of suitable white metal. Several packings have an extra front-packing—*e.g.*, in the Howaldt packing.

Most packings permit a movement of the packing-rings in a direction perpendicular to the axis of the cylinder only; a few others also allow a slightly inclined motion of the rod.

Great care must be taken that the cylinder-cover is well cooled, that the packing-rings are well lubricated, and that they have never to support the weight of the piston-rod. This might happen, however, if, in the course of time, the clearance between the packing-rings and the stuffing-box should

become filled with burnt residues. Therefore it is necessary, from time to time, to remove the packing for cleaning, and for this reason it is advisable to make the stuffing-box a separate and easily removable part (Fig. 13), and not continuous with the cover.

The following description of the various types of gas-engines shows that the pistons, cooled through the hollow piston-rods, differ in construction. They have proved very difficult to design; pistons broke both when they were made in one or more pieces and when they were low or high in tensile strength. With the thicknesses of walls, which are necessary to transmit

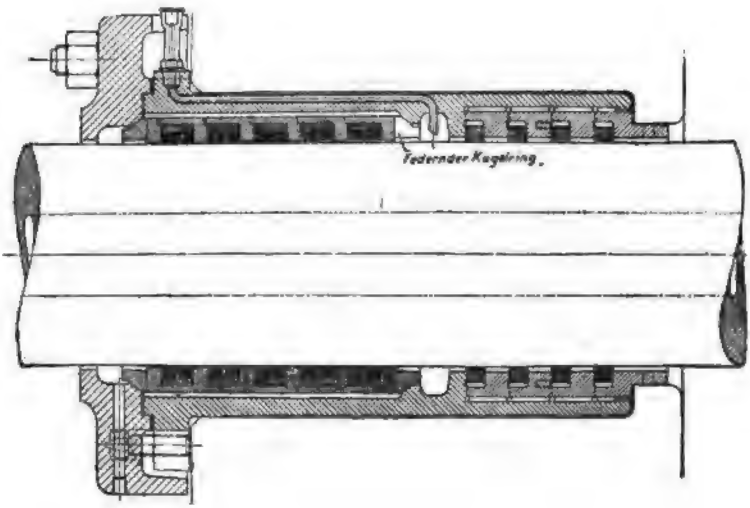


FIG. 13.—THE SIEGER STUFFING-BOX.

the energy of the explosion, the initial stresses in pistons are already dangerous, wherefore it is necessary to reheat the cast-steel pistons after casting. It is, moreover, not advisable to stiffen them with ribs, as these, as is the case with cylinder-heads and cylinder-covers, often are the cause of fracture. With pistons divided into two parts, great attention must be given to the water-tight joint to prevent leakage of the cooling-water, which is below from 3 to 5 atmospheres, at the circumference of the piston, as even the smallest leakage prevents the formation of the electric spark necessary for ignition.

Finally, the fixing of the piston on the rod is a very important point.

The old-fashioned method of securing the piston to the piston-rod by a screwed end and a nut may be employed if the materials of the rod and nut are of very different hardnesses; otherwise, as proved by experience, a slackening of the nut is often impossible. The most practical design for this purpose is certainly that first constructed by Cockerill, in which the two halves of the piston are pressed against a flange, forged on the piston-rod, by small screws, which can easily be slackened.

The cooling of the piston-rod and of the piston is now gen-

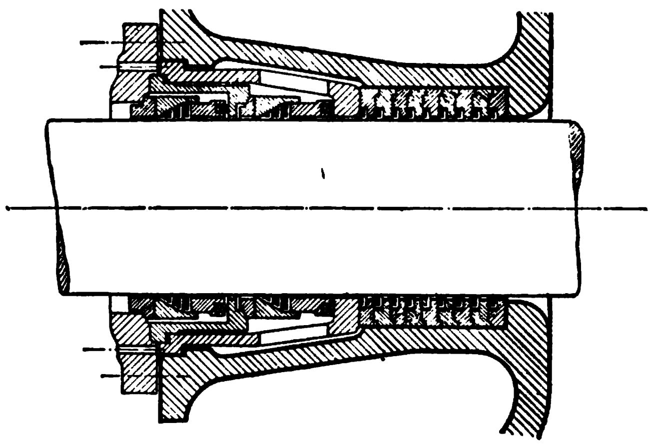


FIG. 14.—STUFFING-BOX OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

erally so arranged that the cooling-water enters the rod at one end and flows out at the other. A flowing-back is avoided by a pipe being fitted in the bore of the piston-rod. In tandem-engines this arrangement is either on each cylinder, or the cooling-water is allowed to pass through both rods and both pistons, one after the other. In the first case the cooling-water must be at a pressure of from 2.5 to 3 atmospheres, and in the second from 4.5 to 5 atmospheres. Concerning the manufacture of the piston-rod, that system is naturally the best by which the axis of the piston-rod, when erected and loaded with the pistons and the water they contain, is a straight line. In order to

attain this end the piston-rod, loaded in this manner, can be turned by keeping the rod fixed and allowing the tool to turn, or the rod is turned with the lathe-centers displaced in such a manner, that at the middle point of a line joining the centers of the end-sections the rod has a deviation which is equal to the deflection of the rod when loaded.

This method is not generally adopted in two-cycle engines, because the piston is too long, being equal to the stroke of the engine; it is also too heavy. The piston is allowed to rest on the

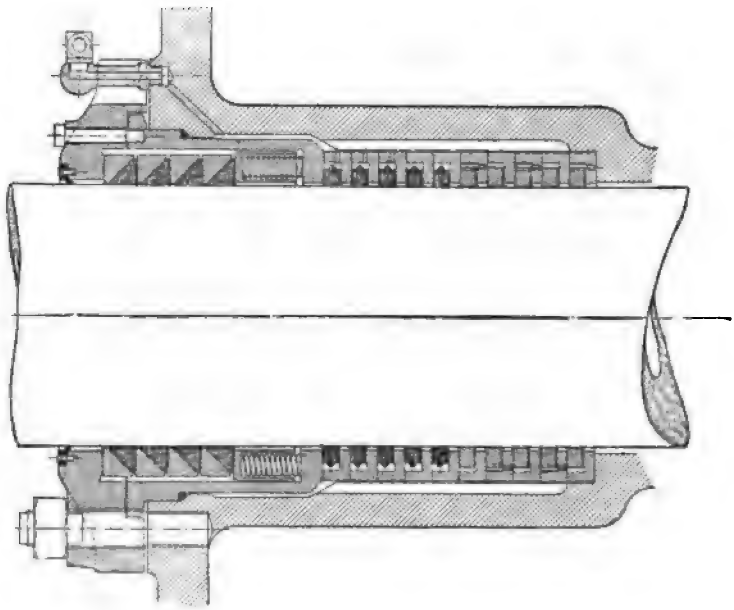


FIG. 15.—STUFFING-BOX OF ELSÄSSISCHE MASCHINENBAU-GESELLSCHAFT.

cylinder at the risk of greater wear of the latter. Although it is evident that a free-bearing piston, which does not unduly load the working-surfaces, and a piston-rod working straight and not arched, are of great value in minimizing wear of the cylinder and maintaining tightness in the stuffing-boxes, yet, on the other hand, the danger of wear of the cylinder through the weight of the piston in two-cycle engines must not be exaggerated. This wear is in any case much greater at the edges of the piston-rings, which often require replacing in large num-

bers, especially when they are made with too strong a spring, than that arising from the weight of the piston. This follows also from experience which was gained with the old four-cycle motors, in which the piston at the same time formed the cross-head, and thereby, in addition to the load due to its own weight, transferred the much greater guiding-pressure to the surface of the cylinder. In these engines wear was principally encountered at that part of the cylinder over which the piston-rings passed and the front portion of the cylinder, but the piston itself showed hardly any signs of wear. Therefore, not more piston-rings should be used than are necessary to keep the long double-cycle pistons tight; moreover, it is better to distribute them at both ends of the piston.

The lower surface of the cylinder, which should be well lubricated, would wear better if the exhaust ports were omitted, for much of the oil blows out through them.

4. *Ignition and Starting.*

A magneto-electric apparatus, driven by the engine, is generally employed for producing the electric spark to ignite the mixture at the end of the compression-stroke. These have in all cases given satisfaction. The induction-spark, by the aid of an accumulator, as employed by the Maschinenbau-Gesellschaft Nürnberg, is also satisfactory. Frequently two igniters at each end of the cylinder are fitted to insure safety and rapidity of the ignition and combustion. Even should one be out of order, the ignition-plugs—which are fitted in the combustion-chamber of the engine, and there carry the levers, by the separation of which the contact is broken and the spark created—were formerly cooled by a circulation of water. This has, however, been found to be unnecessary, and the plugs can now be easily removed without disturbing the water-connections.

The rapid removal of plugs is important, because the presence of bad gas and the non-production of the spark are the principal causes, in modern engines, of a refusal to start; happily this does not often occur. If the magneto-electric apparatus is in good order, it is clearly indicated that the plug is covered with moisture, and hence no spark can be originated.

Dampness can be deposited during the night when the en-

gine is not running, also when the admission- and exhaust-valves are open. In starting it may be condensed and settle from the compressed air used, if this contains moisture. In many plants the rule is to remove the plugs each time the engines are started and thoroughly heat them.

To prevent water or moist compressed air being carried over from the air-holder, care must be taken to drain the latter, also to take the air from the highest point of the holder.

Should ignition fail at one end of the cylinder while the engine is working, this requires the driver's special attention. This failure may be occasioned by a leakage of the cooling-water from the piston, at a pressure of from 3 to 5 atmospheres, by the partial fracture of the piston, of the walls of the cylinder, or of the cover. This water, leaking out during the suction period, squirts against the plugs on the return stroke of the piston.

In such cases, when the driver is convinced that the outer ignition apparatus is in good order, the engine must be stopped and the reason of the ignition failure ascertained; also, if the load on the engine will allow of it being done, one end or one cylinder should be put out of service. If, however, they cannot be spared, at any rate the gas in the cylinder concerned must be shut off, and the compression working cut out, for instance, by wedging up the exhaust-valve. If it is supposed that the piston is cracked, even though the leakage be very slight, the cylinder should only be kept at work in case of great necessity, because the presence of water in the cylinder quickly causes considerable wear. If the precaution is taken to heat the ignition-plugs before starting, and, moreover, to make sure that the gas is suitable and burning with a steady bluish flame, the starting of gas-engines no longer offers the slightest difficulty. Further, since the general adoption of compressed air for starting large gas-engines, the time has passed when hours, and even days, were spent in vain efforts to make the engine start.

The pressure of the air employed ranges from 6 to 25 atmospheres. In most cases the valves work in the same cycle when starting as when running. The compressed air is admitted at what would usually be the commencement of the combustion-stroke and gives the engine a start. The moment of admission

of the compressed air should be determined in consideration of the fact that, in case of an ignition of the gases now drawn in, the combustion-pressure attained is higher than that of the compressed air. Further, no such admission should take place before or during combustion, as it would deteriorate the mixture, In multiple-cylinder engines, particularly two-cycle engines, which can start with a correspondingly small load, starting is often possible by admitting compressed air to one cylinder. In such cases ignition must be allowed to take place in the second cylinder, then the compressed air must be shut off in the first cylinder, and then after a few revolutions, and after the moisture originating from the compressed air has been evaporated by the heat developed by compression, the gas-valve in the first cylinder must also be opened. In starting gas-engines the ignition mechanism must be so arranged that ignition of the mixture takes place at a time which corresponds to a smaller crank-angle, distant from the dead center, than obtains at the regular speed. In the same manner the ignition must also be regulated by hand if the number of revolutions of the engine is variable, as is the case with gas-blowers.

V. The Various Types.

1. *Double-Acting Four-Cycle Engine of the Maschinenbau-Gesellschaft Nürnberg.* (Figs. 16, 17, 18, 19, 20, 21, 22, and Plate I.)

This firm and their licensees, Haniel & Lueg, Düsseldorf, and Friedrich-Wilhelmshütte, Mülheim on the Ruhr, have, if size and horse-power are taken into consideration, constructed the greatest proportion of large gas-engines in Germany, including the largest units, namely, twin tandem engines from 3,600 to 4,000 brake horse-power.

As shown by the Nürnberg single-cylinder engine (Figs. 16, 17, 18), and by the tandem engine driving a blowing-cylinder also in tandem (Plate I.), the design is very similar to that of steam-engines.

The graceful form and the careful design of the principal parts of the Nürnberg engines are clear from the figures, and require no further comment.

The frame of the engine is open at the top to render the

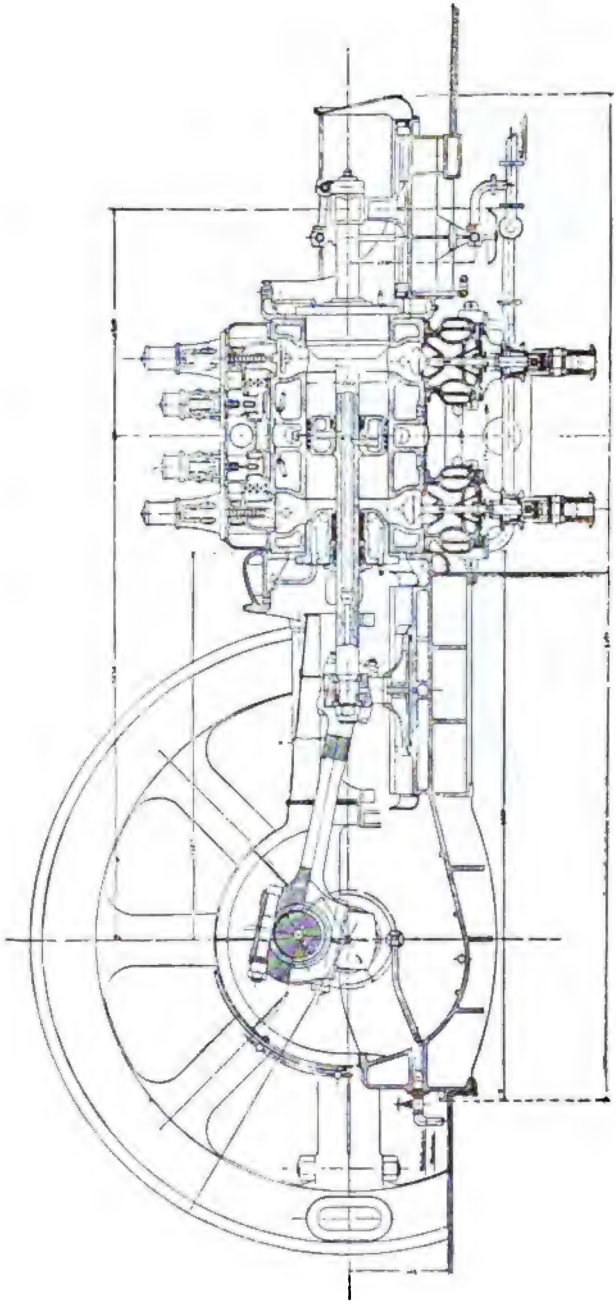


FIG. 16.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

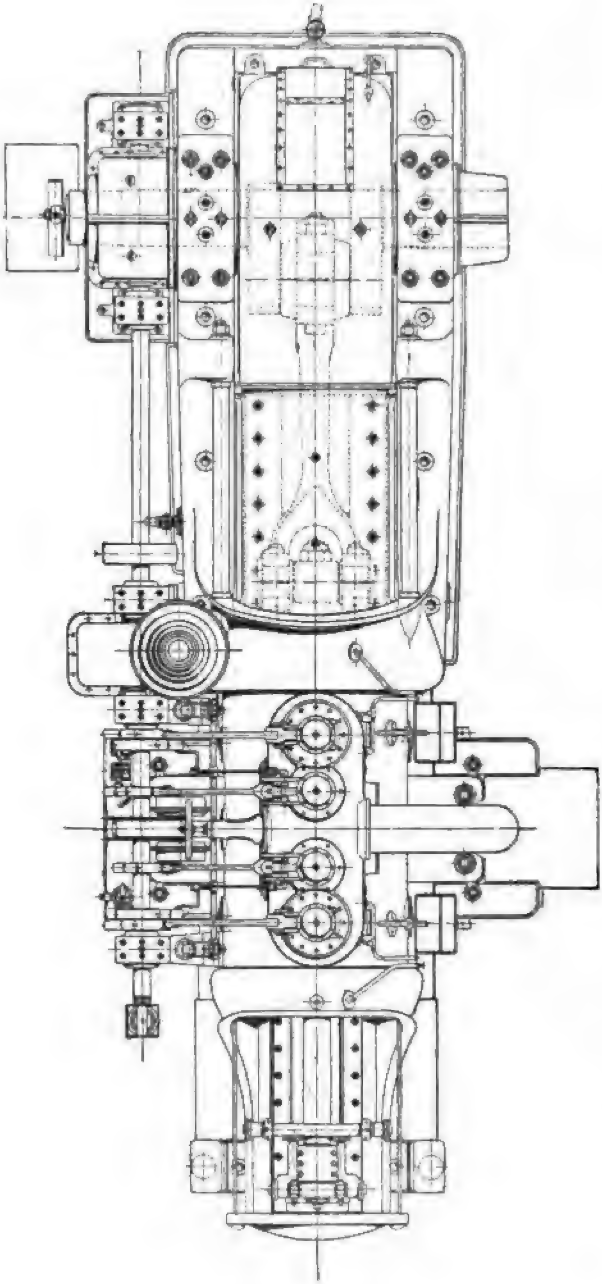


FIG. 17.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

crosshead, stuffing-box, and cylinder-cover accessible; but the opening is entirely covered with a plate when the engine is running. The open frame terminates in a strong circular flange to form a concentric point with the cylinder; the flange

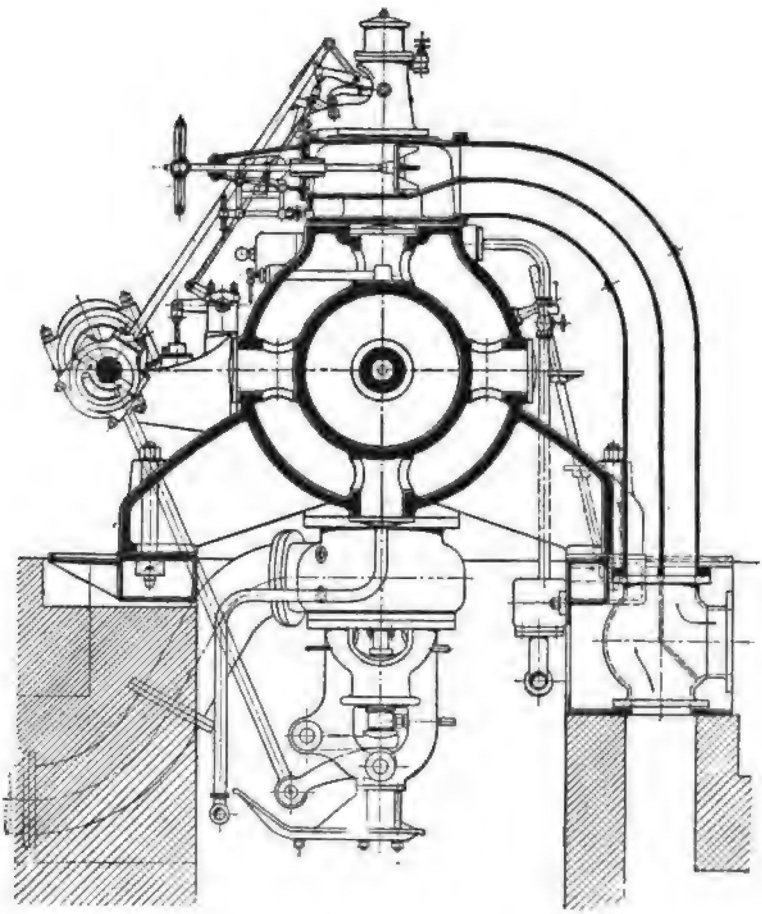


FIG. 18.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

is strengthened by tension-rods extending to the part which forms the crank shaft-bearing. The distance-pieces, which are also strengthened by tension-rods, unite the separate cylinders in a similar concentric manner. Owing to this method of construction the erection of the engine is easy and exact. The

lower portion of the distance-pieces (Plate I.) form the crosshead guides for supporting the piston-rods; and the upper portion is provided with an opening through which the cylinder-cover and piston can be removed.

The cylinders are entirely symmetrical, with wide flanges forming large cooling-spaces. A number of examination-doors are provided for clearing out, when necessary, any deposit. At each cylinder end there is an inlet-valve above and an exhaust-valve below; and these valves are situated well outward from the cylinder-walls, so that the highest temperatures occurring have to extend their influence along the axes of the valves to the outer valve-boxes.

The gearing of all the valves is operated by an eccentric and roller-levers. The gas-valves are situated in the longitudinal axis of the cylinder close to the inlet-valves, and their motion is controlled by the governor.

For the method of governing and the formation of the mixture and of the exhaust-valve chambers, the author would refer to what has already been mentioned (p. 30).

The pistons are cast hollow but in one piece, and are pressed on to the conical part of the rod by nuts recessed into the pistons. By this means the front and back cylinder-covers can be made symmetrical.

The lubrication of all the working-parts is arranged in an effective manner from a central position.

Fig. 19 shows a Nürnberg tandem engine with the front cylinder-covers removed, and prepared ready for cleaning the front valves.

With the front cover removed the front exhaust-valve is accessible from the crosshead guide and under the piston-rod. Attention is, however, drawn to the fact that, after having screwed off the cylinder-cover and taken off the heavy cover in the manner described, this valve is accessible, although not altogether easily. Much stress should not be laid on this accessibility with cylinders of less than 500 horse-power.

This applies to all systems in which the exhaust-valves are placed below the piston-rod.

The cleaner the gas and the purer the water for cooling the

valves, the less important is it that the valves should be easily accessible.

The construction of the blowing-cylinder of the Maschinenbau-Gesellschaft Nürnberg can be seen from Plate I.

The inlet-valves are controlled by an eccentric on the crank-shaft and a link-motion with long rods, in such a manner that, with an equal power of the engine, should the air-pressure become higher than usual, a smaller quantity of air is drawn in, also giving relief when starting. The pressure-valve gear consists of valves preceded by slide-valves, so controlled that they open much earlier than the pressure-valves, but at the dead center they close and thus give the pressure-valves (which are loaded with light springs) time to close. Seeing that while the volumetric efficiency, both with isothermal and adiabatic compression, is without influence on the work to be done per unit of the quantity of air compressed, the heavy and copious lubrication required by pressure slide-valves may only favor the use of valves with a long lift and with light spring pressure.

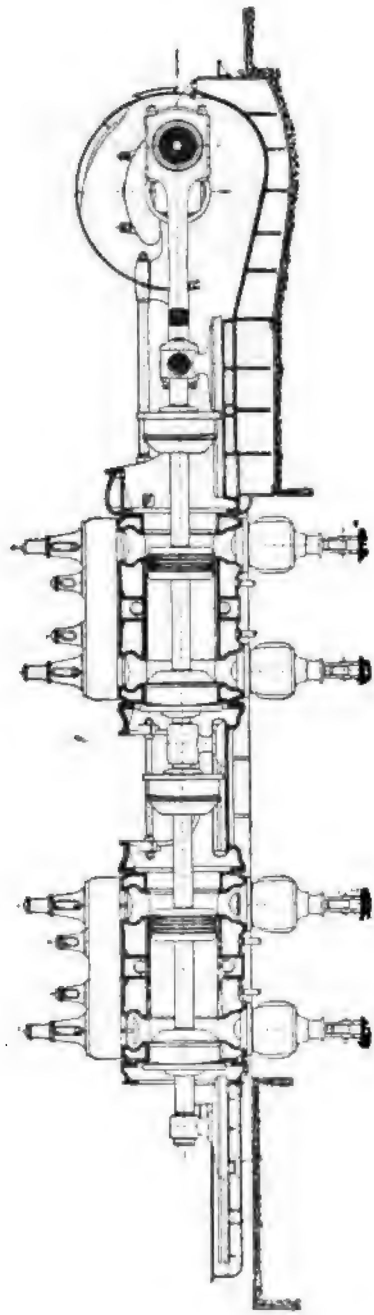


Fig. 19.—Double-Acting Four-Cycle Engine of Maschinenbau-Gesellschaft Nürnberg.

2. *Double-Acting, Four-Cycle Engine of the Gasmotorenfabrik Deutz.* Figs. 23, 24, 25, 26, and Plate II.

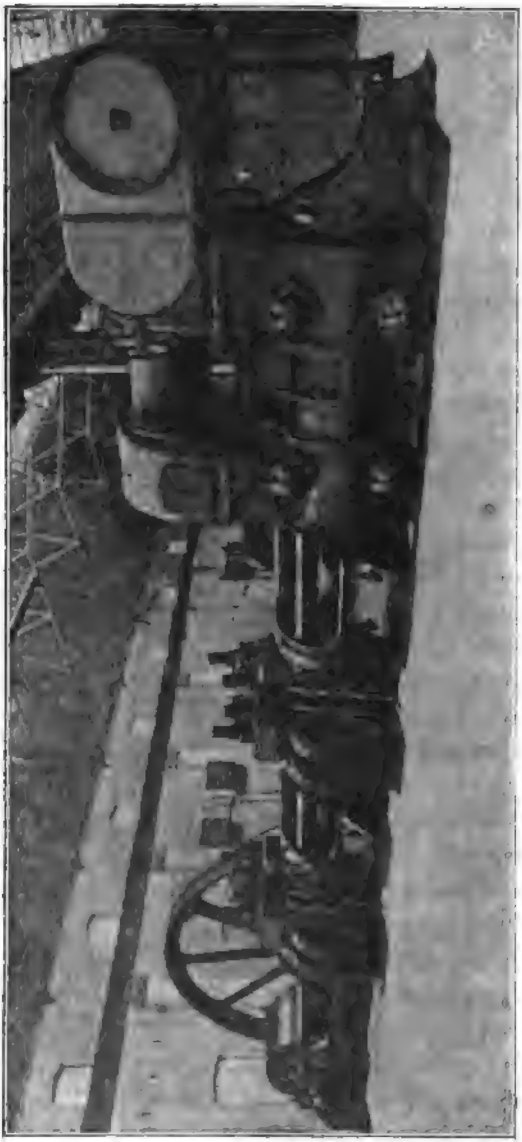


FIG. 20.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

The Gasmotorenfabrik Deutz engines have lately been described by Professor Meyer.[15]

The details of the cylinder of a 250 h.p. single-cylinder en-

[5] *Stahl und Eisen*, vol. xxv., pp. 67 to 72, 132 to 144 (1905).

gine have already been described. This was the first engine of this type constructed by the Gasmotorenfabrik Deutz. Having regard to what has already been stated, the peculiarities of the

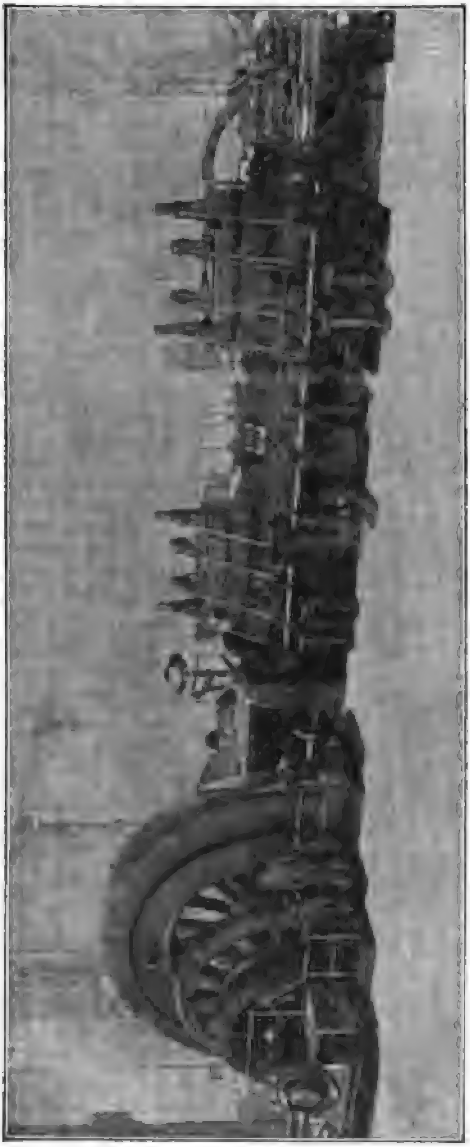


FIG. 21.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

construction require no further explanation. It may be remarked that in these smaller engines the guides are of the circular inclosed type (Fig. 23).

The valve-gear of this engine is actuated by cams, and the quantity governing (with a constant mixture) is attained by throttling; by the governor working with a movable fulcrum

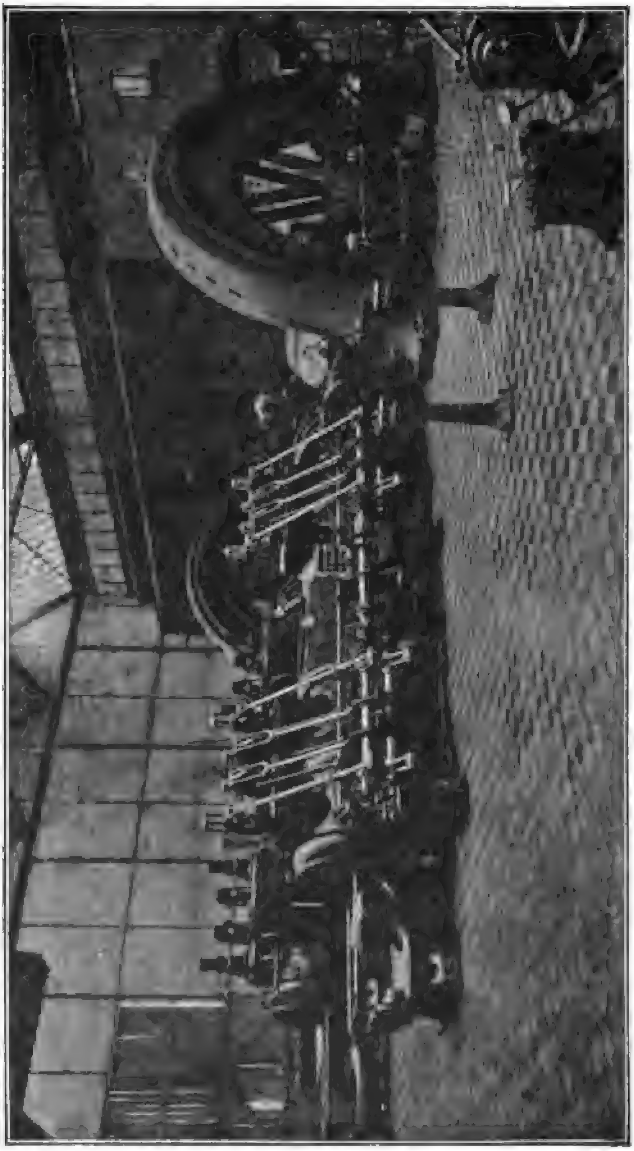


FIG. 22.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF MASCHINENBAU-GESELLSCHAFT NÜRNBERG.

on the lever of the inlet-valve, by which means the lift of the inlet-valve is increased or reduced. This arrangement of the valve-gear is simple, as no special gas valve has to be controlled.

It would not, however, be suitable for engines with two or more cylinders, say with four inlet-valves, for the movable fulcrum of at least one valve-lever would be fixed by the action of a strong valve-spring, and thereby the governor would encounter excessive resistance. For this reason the Gasmotorenfabrik Deutz, in their latest engines, have placed, at the side of the

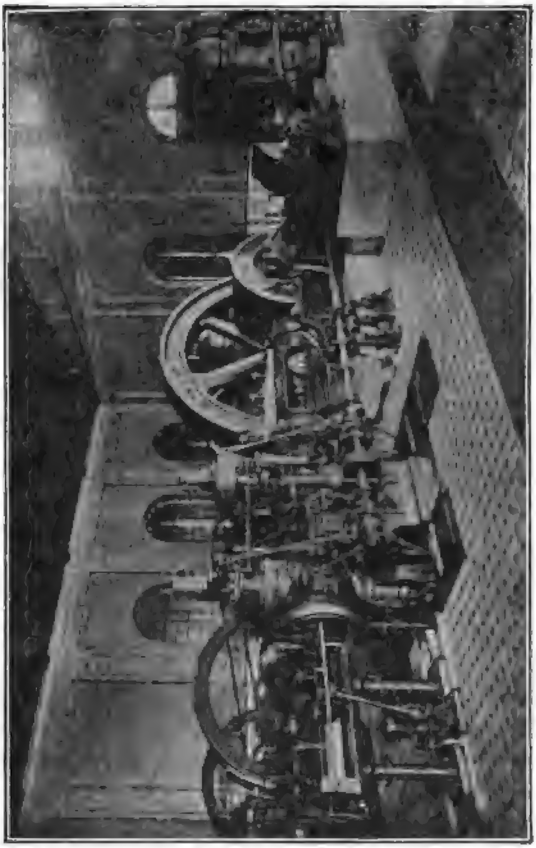


FIG. 23.—DOUBLE-ACTING FOUR CYCLE ENGINE OF THE GASMOTORENFABRIK DEUTZ.

principal valve, a special mixing-valve for the admission of gas and air, so that when the governor operates, the fulcrum of the lever of the main valve is fixed while that of the mixing-valve is moved (Fig. 24), thereby considerably reducing the resistance to the governor, and, moreover, the mixing-valve is rendered accessible for cleaning.

Seeing that the mixing-valve is controlled by the mechanism

of the main valve, the gear is simple. From Fig. 24 it will be further seen that the Gasmotorenfabrik Deutz has introduced a

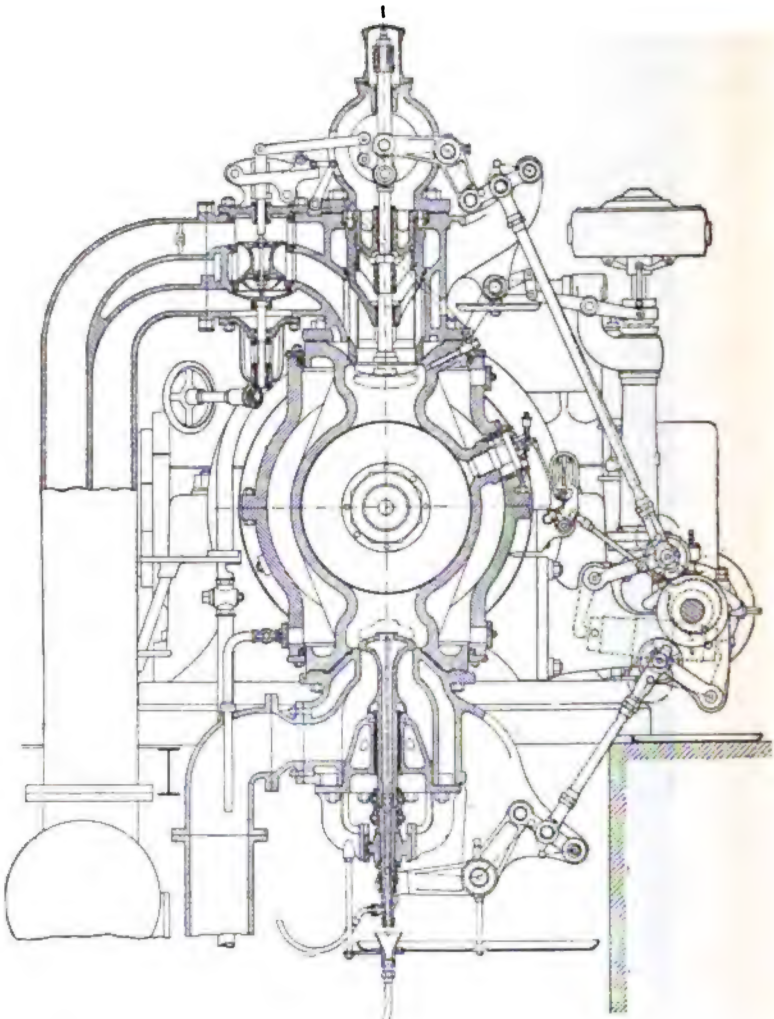


FIG. 24.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF THE GASMOTORENFABRIK DEUTZ.

patented arrangement of a bell-crank lever in front of the valve-levers, which, on the one hand, replaces the action of rolling-levers in lifting and closing the valves, and, on the other hand,

prevents undesirable opening of the valves, which may occur when the engine is lightly loaded or running without load.

When the valve is closed the bell-crank lever is in its limiting position, so that the forces transmitted by the valves can cause no bending of the bell-crank lever, and therefore no motion. As shown in Fig. 24, the Gasmotorenfabrik Deutz now makes a complete separation of the inner and outer cylinder walls at the intersection with the valve-chambers, whereby the stresses due to heat are reduced.

The arrangement of the governor-gearing of the Deutz engine here described gives only a downward resistance for the fulcrum of the lever of the mixing-valve. Should the valve-spindle or the spindle-guides become dirty and stick, the weight of the mixing-valve and the pressure of the spring are no longer sufficient to overcome the resistance, and the action of the governor will be unreliable.

In the construction of their 2,000 h.p. tandem engine (Fig. 25, Plate II.) this possibility is, however, removed, because, in this engine, the lever of the mixing-valve is made in the form of a closed link, which on both sides incloses the movable fulcrum. The movable fulcrum of the mixing-valve lever is thereby the end point of a lever capable of being turned on a fixed center by the governor, the length of which represents the radius of the curve of the link. In this case the strong spring of the inlet-valve, together with the weight of the mixing-valve and its light springs, aid the closing of the valve.

The Gasmotorenfabrik Deutz construct the frames of this type of engine (Plate II.) open at the top. Each cylinder consists of a cast-iron liner, to which the cast-steel cylinder-heads are bolted by means of flanges. The outer jacket is then completed by a circular casting in two pieces.

Although this construction, in my opinion, is not safer than that in which the cylinder-heads and the liner were cast together, it has the advantage that the simple cylinder-liners can be easily made of hard cast-iron.

The valve gearing is operated by round-back cams with roller-levers (Fig. 25); at each cylinder end there is only one cam for the simultaneous operation of the inlet- and outlet-valves.

The last-mentioned is double-seated in a manner similar to

the valves of steam-engines; but as, however, exhaust only takes place at the top seating, the deposit of dirt and cinders on the bottom seating must be considered.

The roller-levers of the inlet- and outlet-valve gearing can be put out of gear by hanging the roller-path to the levers,

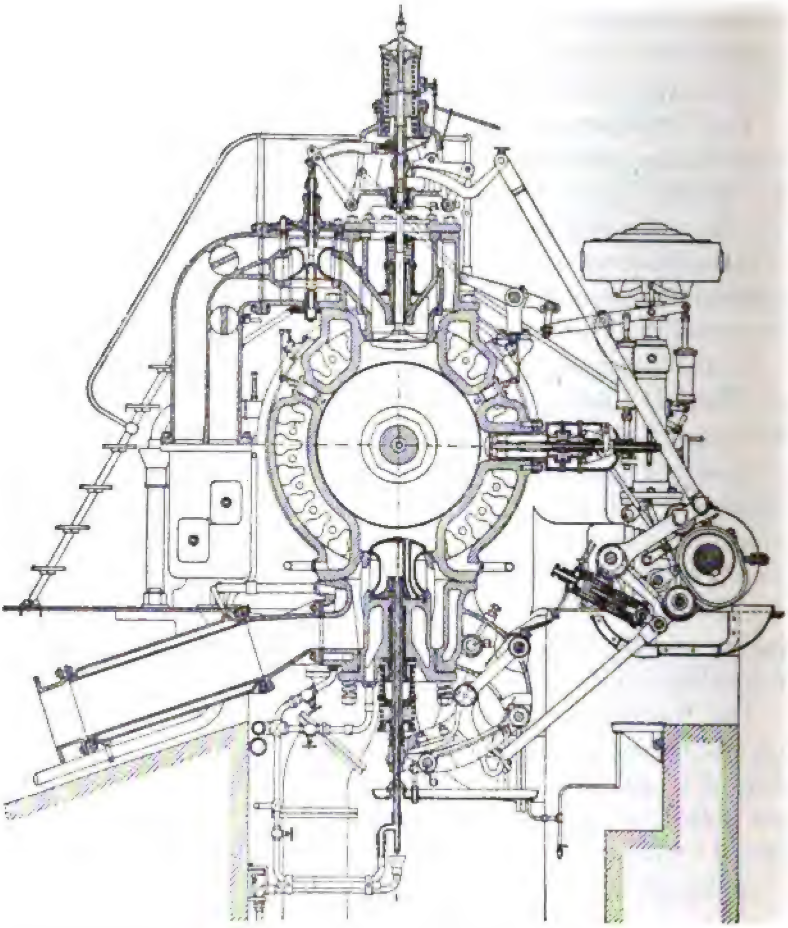


FIG. 25.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF THE GASMOTORENFABRIK DEUTZ.

which can be interspersed round the eccentric pins *a*, *a* (Fig. 25). With the exhaust-valve gearing the whole system of rods can be disconnected from the outlet-valve spindle by removing a bolt, *b*, so that the outlet-valve with its seating can be taken down.

This engine, as represented in Fig. 26, is at work at the Hoerder Verein Ironworks, and is remarkable owing to its ele-

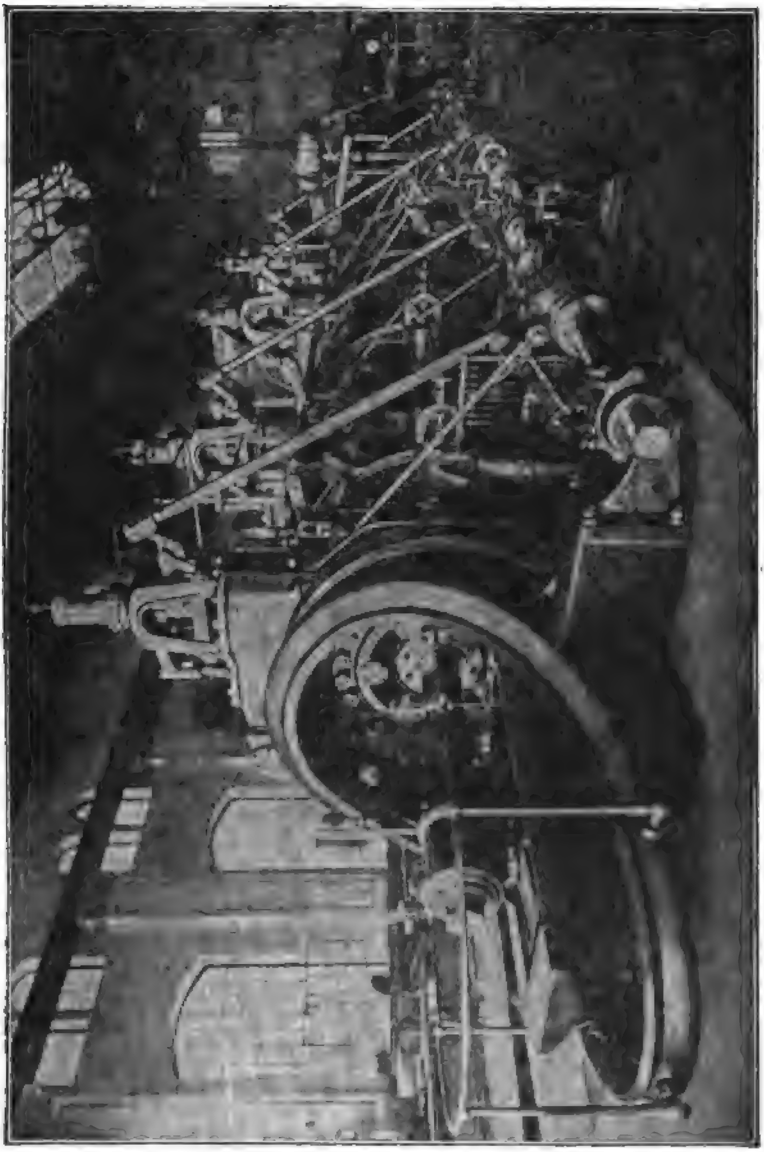


FIG. 26.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF THE GASMOTORENFABRIK DEUTZ.

gant design, strong construction, great simplicity, and faultless working.

3. *Double-Acting Four-Cycle Engine by Ehrhardt & Sehmer, Schleifmühle.* (Figs. 27, 28, 29, 30, and Plate III.)

Ehrhardt & Sehmer are licensees of the Gasmotorenfabrik Deutz. Their gas-engines are constructed, as those of the

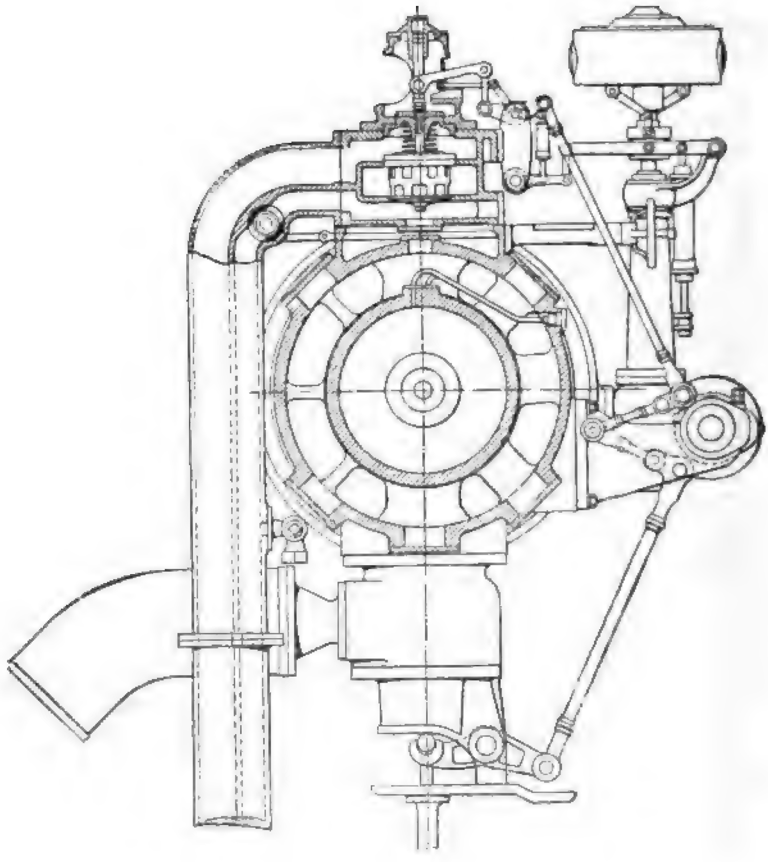


FIG. 27.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF EHRHARDT & SEHMER.

latter, with quantity governing, but in other respects they have not retained the outer arrangement of the Deutz engine; for instance, with respect to the operation of the mixing-valve. The inlet-valves and mixing-valves are in a similar erection in the longitudinal axis of the cylinder, as is the case with the Nürnberg engine, with this exception, that in the Ehrhardt &

Sehmer engine each valve, including the mixing-valves, is operated by a round-back cam (Figs. 27, 28).

The mixing-valves are, according to information received from the firm, arranged in such a manner that, for working

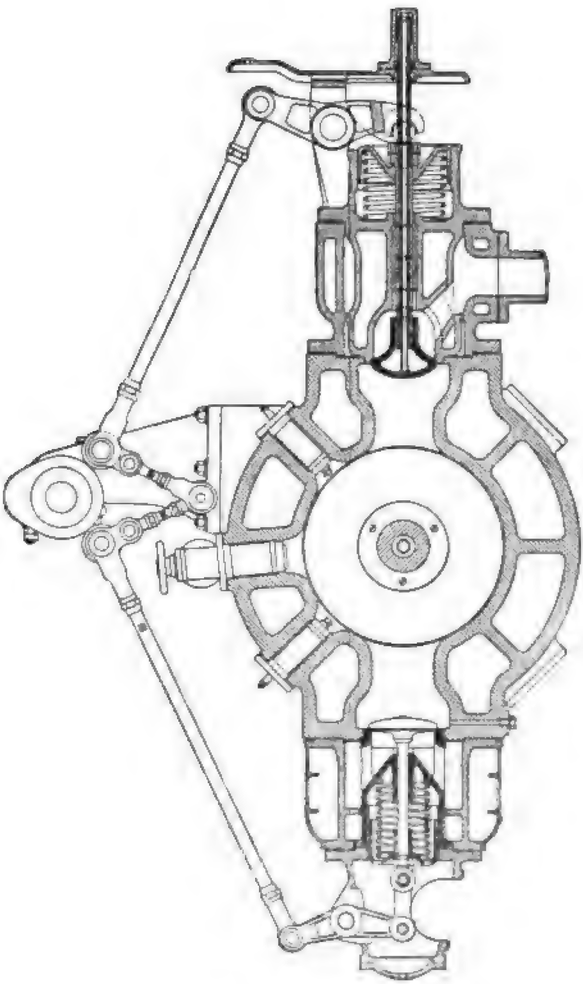


FIG. 28.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF EHRHARDT & SEHMER.

with various gases, the area of the valve-passage can be varied.

The cylinders have large water-cooling spaces. They and the water-jacket are cast in one piece, and are, as in the case of the Nürnberg engine, supported by the frames, by the distance-piece, between the cylinders, and by the back guide. The

outlet-valves can be removed, with their casings, without disconnecting the piping, the space under the cylinders being en-

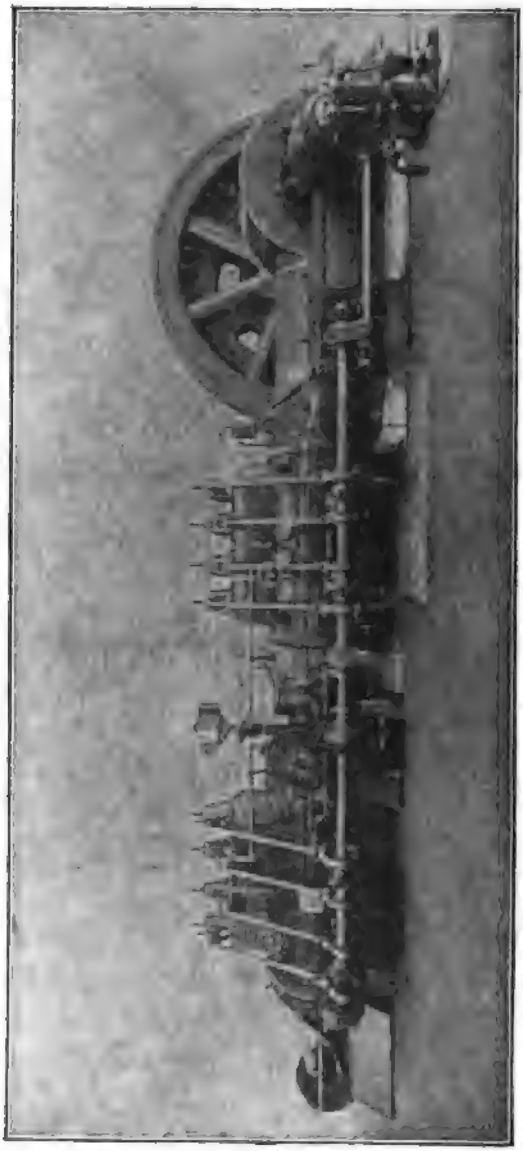


FIG. 29.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF EHRHARDT & SEHMER.

tirely free. It will be seen from the figures that all the details of this engine are well made and of strong proportions.

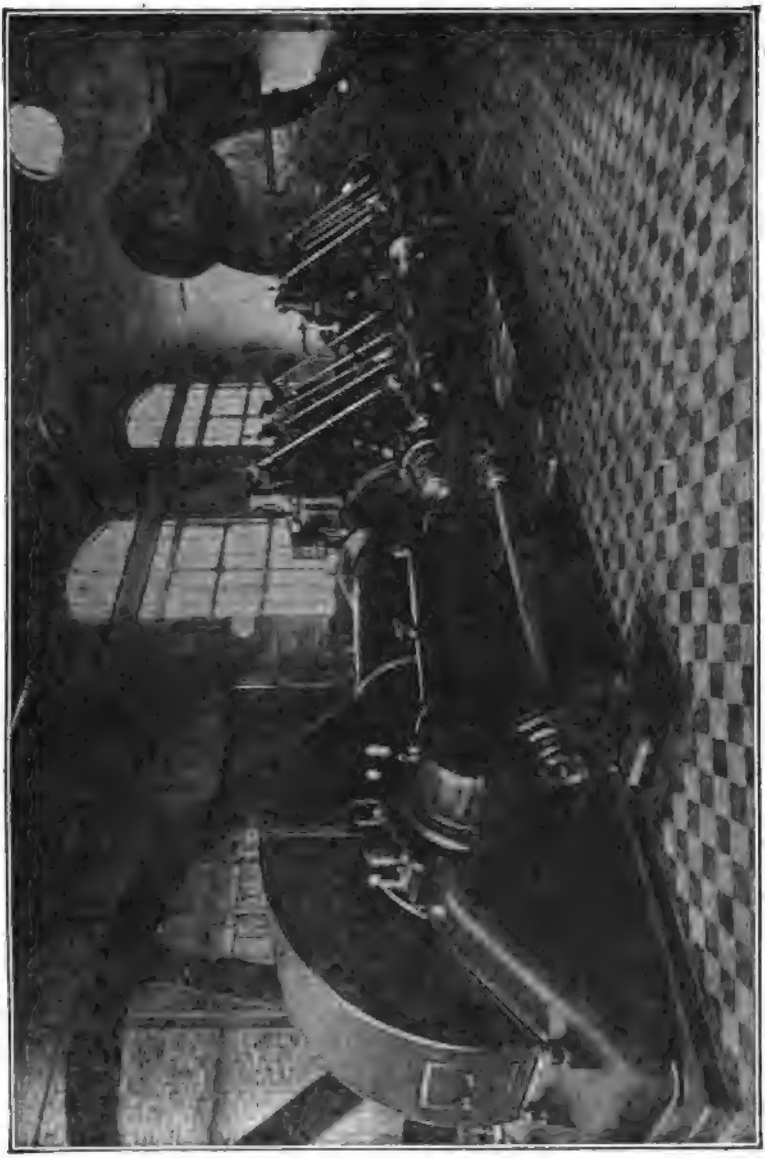


FIG. 30.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF EHRHARDT & SEHMER.

4. *Double-Acting Four-Cycle Engine by the Märkische Maschinenbau-Anstalt, Wetter-Ruhr.* (Plate IV.)

The Märkische Maschinenbau-Anstalt is the licensee of the Belgian firm, Cockerill, and adheres to their design.

The massive frame supports the guides between two high

cheeks, which in tandem engines are continued to the back cylinder, and the stresses are thus transferred to the crank-shaft bearing.

Less objection can be made to this manner of construction than to the retention of the class of cylinder-heads that are so liable to fracture—even though they are closed with a cylinder-cover—and to the construction of such cylinder-heads, each cast in one piece with one of the cheeks of the frame.

Cockerill themselves discarded this construction in the engines they exhibited at the International Exhibition of Liège, while they no longer construct the cylinder-heads, nor cast the cylinder together with the side-cheeks of the frame.

In Plate IV. it may be further observed that the outer casing is divided in the middle and closed by a ring, which is slipped over and made tight by short stuffing-boxes. The valves are operated by cams and roller-levers.

Up to the present time the Märkische Maschinenbau-Anstalt have built their engines with quality governing; they propose in the future to employ the quantity method of governing.

The arrangement for admitting the water for cooling the pistons is very carefully designed. Water is admitted by means of a combination of a turned tube with a telescope sliding-pipe. The water is conducted away from the piston-rod by a pipe, screwed into the piston-rod, which travels backwards and forwards in a slot in the cover of a trough. To remove the exhaust-valve the whole valve-casing must be disconnected from the pipe.

5. *Double-Acting Four-Cycle Engine by the Elsässische Maschinenbau-Gesellschaft, Mülhausen.* (Figs. 31, 32, 32A, 33, and Plate V.)

This firm originally, as the licensees of the company, also constructed engines of the Cockerill type; latterly, however, they have entirely modified their designs. This may be seen by comparing the engine of the Märkische Maschinenbau-Anstalt (Plate IV.) with the tandem blowing-engine of the Elsässische Maschinenbau-Gesellschaft (Plate V. and Fig. 31).

Two such engines, each of 1,500 h.p., have been working for a considerable time at the Differdingen Ironworks, and are remarkable for their steady running, and, as maybe seen from Plate V. and Fig. 32, for their well-designed forms and well-

thought-out design of all details. The frames consist of two girders, symmetrical with the longitudinal axis of the engines, joined together by cross-pieces, which join the massive flanged

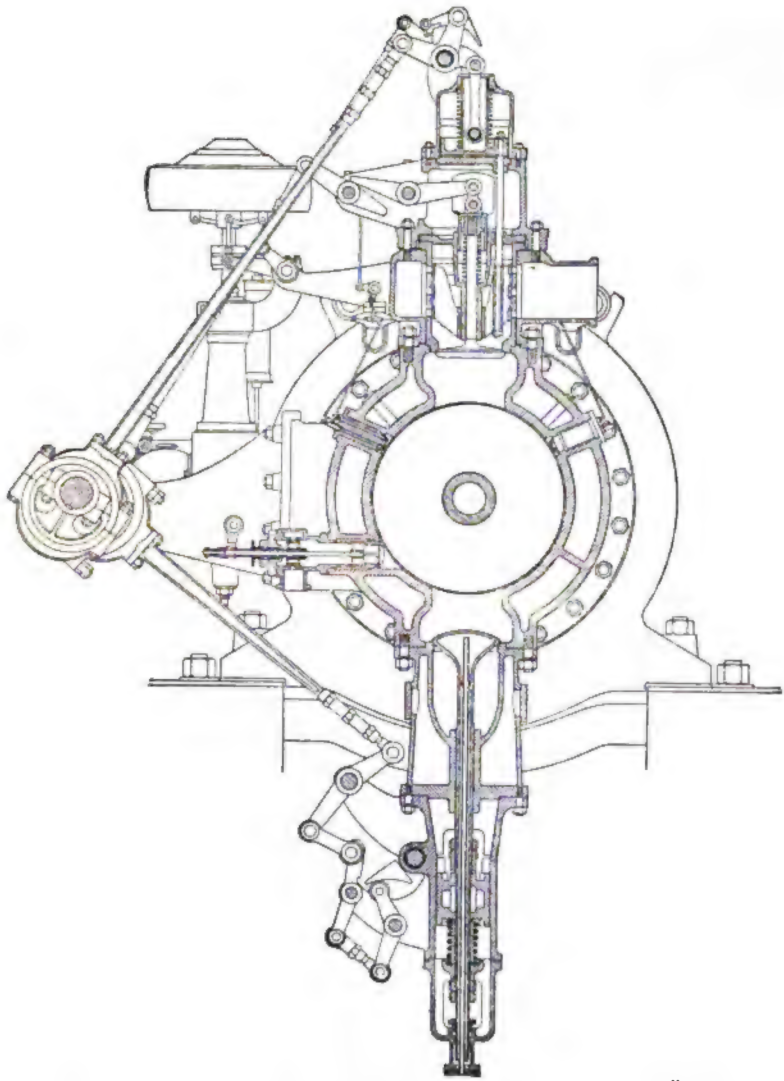


FIG. 31.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF THE ELSÄSSISCHE MASCHINENBAU-GESELLSCHAFT.

ends of the frames to the crank-shaft bearings, whereby the stresses caused by explosion are transmitted to the crank-shaft bearing, without any bending moment, in the vertical plane

The gas-pistons can be very easily removed by detaching the crosshead, the couplings and the cover, while the front piston can be taken out at the front, and the back piston at the rear in the distance-piece between the gas- and blowing-cylinder; the piston-rod of the back gas-cylinder is pushed into the hollow piston-rod of the blowing-cylinder.

The governor regulates quantity, governing in such a manner that it causes a mixing-slide, opening with the inlet-valve, to close suddenly sooner or later (Fig. 31). So long as the mixing-slide remains open, it allows the inlet of air at one half of the chamber (Fig. 33), separated by a vertical partition, and gas at the other half. The mixture is formed by the motion of the air and gas together when passing the inlet-valve, and is quite effective.

The gearing of the inlet- and outlet-valves is controlled by an eccentric and roller-levers, and the outlet-valve is opened and closed with a restricted motion, and after closing it is kept closed by the action of only a short strong spring (Fig. 31).

As may be seen from Plate V., in order to dismount the outlet-valve the valve-casing must be unbolted from the cylinder and the pipe-connections.

The blowing-cylinder is water-cooled, and provided with suction- and pressure-valves on the Hörbiger & Rogler system, and the piston is rendered tight by two piston-rings, made in halves and lined with white metal, and pressed against the walls of the cylinder by springs. To render an increase of the air-pressure possible (in this case from 0.5 to 1 atmosphere), the covers of the blowing-cylinders are provided with chambers, which can be put into communication with the cylinder by means of valves operated by hand. Thereby the clearance-spaces are increased, and, for an equal load of the gas-engine, a corresponding higher pressure with a smaller quantity of air per revolution is attained.

For this increase of air-pressure three steps from 0.5 to 1 atmosphere are provided for by three chambers in the covers. A fourth chamber is arranged with a special valve as a circulating space for starting the engine with a relieved load.

6. *Double-Acting Four-Cycle Engine by Fried. Krupp Aktien Gesellschaft, Essen-Ruhr.* (Figs. 34 and 35.)

This motor, which this firm have several times constructed for their own use, is worthy of notice, owing to the arrangement of the valves and the construction of the cylinder.

Both the inlet- and the outlet-valves are situated above the cylinder, in its longitudinal axis, together in the same cast-steel valve-chamber (Fig. 34). As compared with the outlet-valve

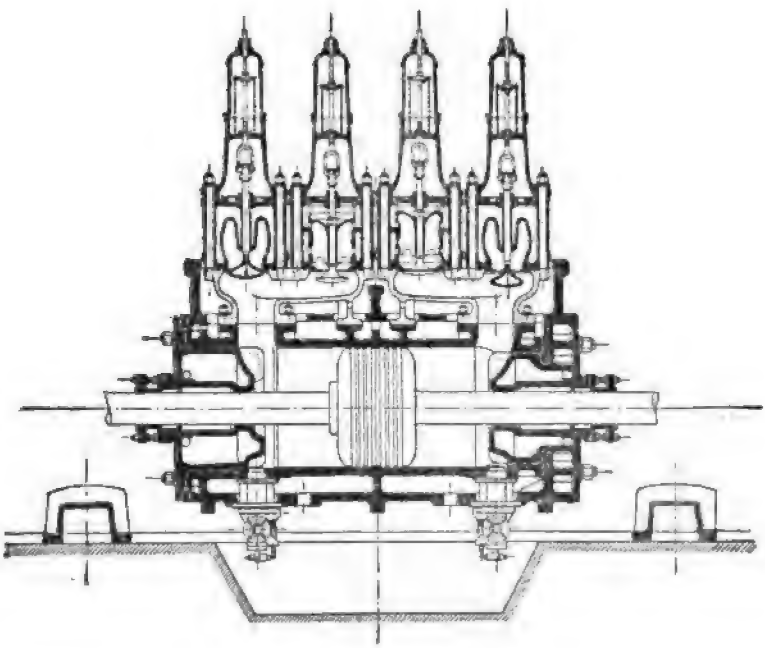


FIG. 34.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF FRIED. KRUPP AKTIEN GESELLSCHAFT.

situated under the cylinder, the advantage of the easy accessibility by direct lifting by a crane or traveler, of the possibility of easily examining the whole of the valve-motion, as well as of the unbroken foundation bed-plate, is very obvious.

The cylinder-liner is provided with short shoulders to receive the valve-chambers, inserted into the jacket, which is open at the top, and at the front end is bolted to the same; while at the other end the liner and the jacket are made tight by a short stuffing-box, in such a manner that the liner is free to expand independently.

In this construction of cylinder the stresses caused by heat, that usually occur when the liner and the jacket are cast together, are avoided.

The cylinder is fixed to the frame by means of massive attachments cast on to the jacket (Fig. 35). The quantity method of governing is adopted.

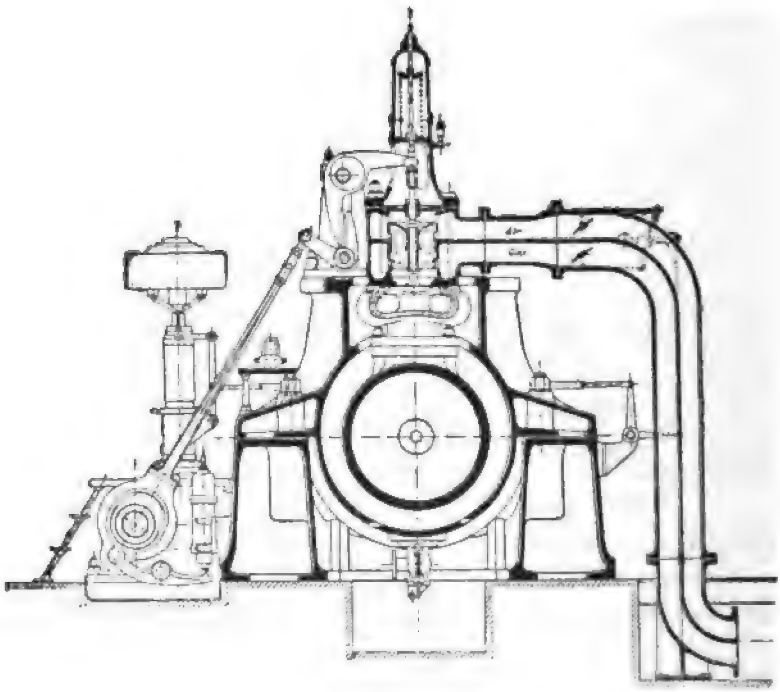


FIG. 35.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF FRIED. KRUPP AKTIEN GESELLSCHAFT.

7. *Double-Acting Four-Cycle Engine by the Gutehoffnungshütte, Oberhausen.* (Fig. 36, and Plate VI.)

The Gutehoffnungshütte, in addition to two-cycle engines on the Körting system, also build four-cycle engines.

Their type of engine is represented in Plate VI. and Fig. 36. The arrangement of the frame of the cylinder, cover, and distance-pieces has already in several instances been described.

One of the inlet-valves above the cylinder and one of the outlet-valves situated under the cylinder are operated by the same cam with roller-levers.

The outlet-valve can be removed without disconnecting the piping.

The mixing-valve for quantity governing (Fig. 36) is situated at the side of the inlet-valve, and is actioned by a release mech

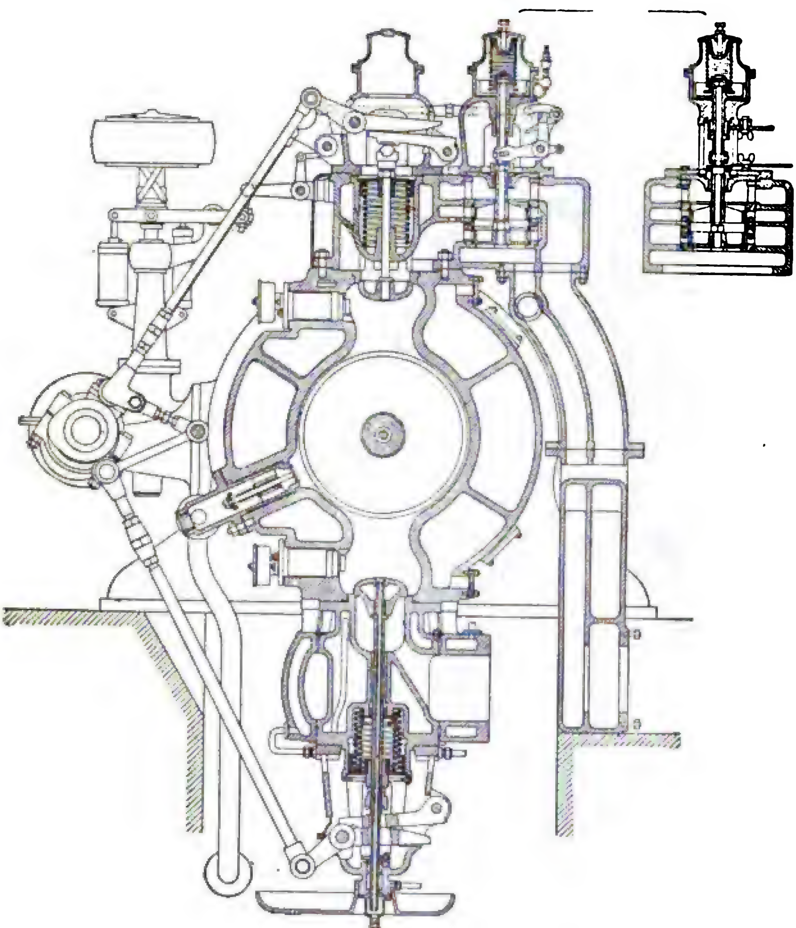


FIG. 36.—THE GUTEHOFFNUNGSHÜTTE DOUBLE-ACTING FOUR-CYCLE ENGINE.

anism actuated by the governor. For the admission of air and gas there are two circular slides on the same axis, so arranged that their openings can be separately regulated to obtain the best mixing during the working of the engine.

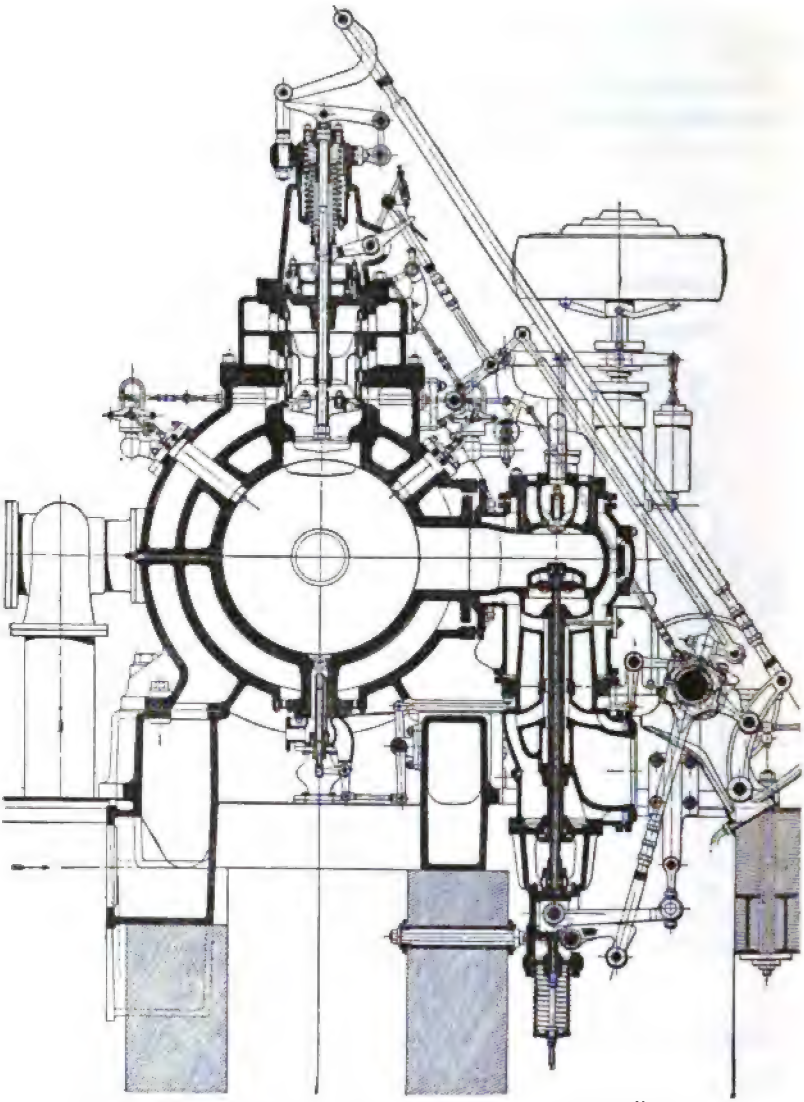


FIG. 37.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF SCHÜCHTERMANN & KREMER.

8. *Double-Acting Four-Cycle Engine by Schüchtermann & Kremer, Dortmund.* (Figs. 37, 38, and Plate VII.)

The Schüchtermann & Kremer engines, in the construction of which I have participated, differ from other types, principally by the outlet-valve being placed at the side of the cylinder in order to be more accessible, and by the previously described

system of governing for producing a constant quantity of mixture

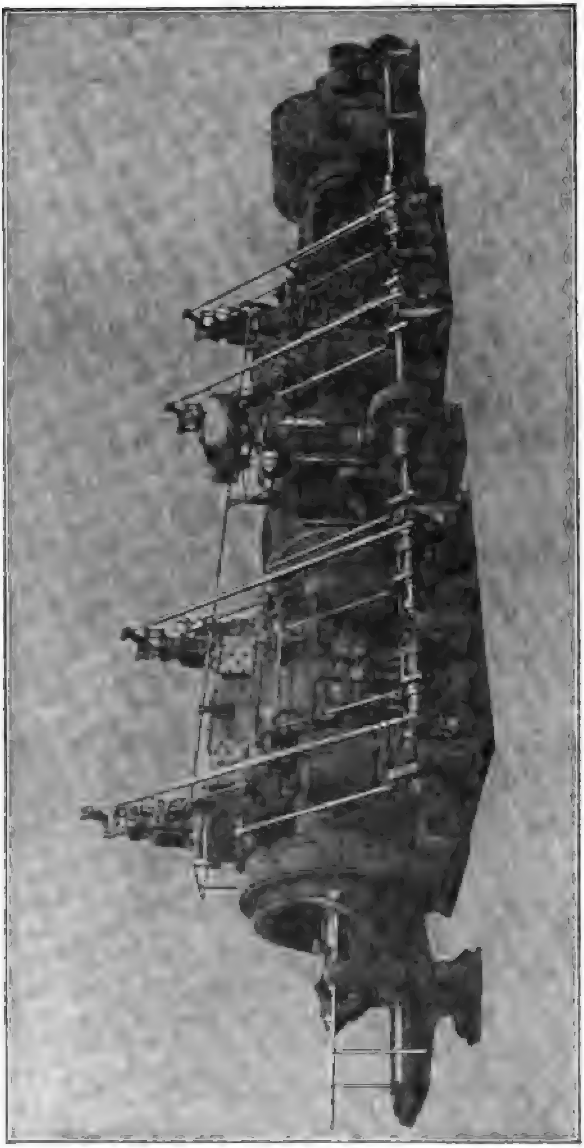


FIG. 38.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF SCHÜCHTERMANN & KREMER.

and constant compression (Fig. 12). Both arrangements have given good results.

9. *Double-Acting Four-Cycle Engine by the Maschinenbau-Aktiengesellschaft Union, Essen-Ruhr.*

Plate VIII. and Figs. 39, 40 show the construction of this engine.

This construction is characterized by the Reichenbach valve-gear (Fig. 39), and also by the manner in which the cylinder is constructed.

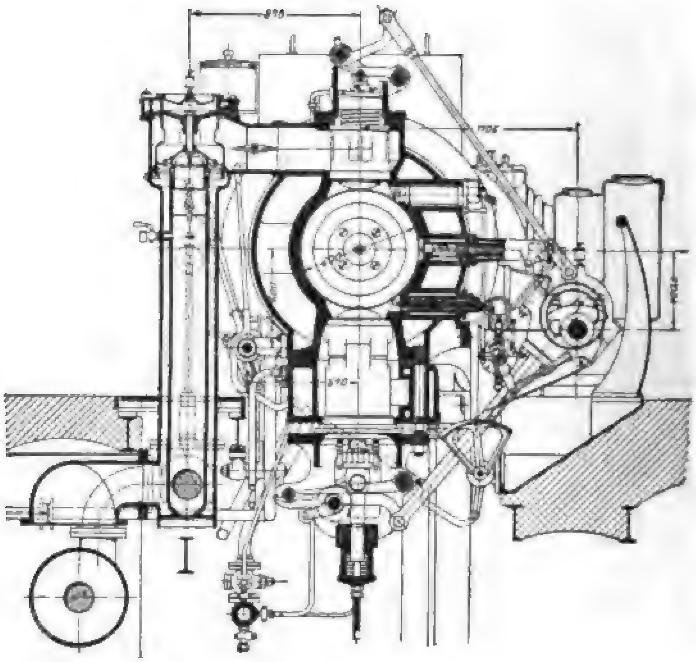


FIG. 39.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF THE MASCHINENBAU-AKTIENGESELLSCHAFT UNION.

The outer jacket is partly open in the middle in a manner similar to that of the Gasmotorenfabrik Deutz engine, and covered by a plate cylinder; further, the jacket near the two end flanges is split after casting, and rendered tight by joints of rubber cords and wire.

Thereby conflicting stresses of the inner liner and of the outer jacket, caused by their different temperatures, at least in a longitudinal direction, are avoided, and also those of the flanges.

These flanges transfer the stress due to explosive action, by massive points, to the liner only.

One inlet-valve and the corresponding outlet-valve are operated by an eccentric with roller-levers. The inlet-valve is indeed unnecessarily cooled. It is stated by the makers that the hollow disk of the outlet-valve can be withdrawn through the cylinder by removing a screw. In large gas-engines the mixing-valve should not be automatic, but moved by the valve-gear shaft, and placed nearer to the inlet-valve in order to avoid a large reserve of mixture.

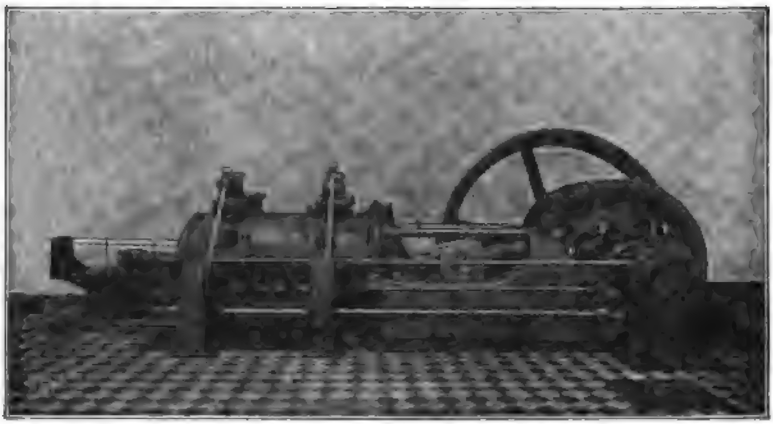


FIG. 40.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF THE MASCHINENBAU-AKTIENGESELLSCHAFT UNION.

10. *Double-Acting Four-Cycle Engine by the Duisburger Maschinenbau-Aktiengesellschaft, formerly Bechem & Keetman, Duisburg.* (Figs. 41, 42, and Plate IX.)

This engine is noteworthy in many ways. It has at the top of each end of the cylinder an inlet-valve and vertically under the same an outlet-valve, arranged in such a manner that the common axis of the valves is far enough to the side of the piston-rod to allow the outlet-valve with its spindle to be lifted up without hindrance when the inlet-valve and its seating has been removed (Fig. 41).

Further, a closed-link motion, automatic in action, with the working-piston as used in two-cycle engines, is employed, as well as an outlet-valve for the exhaust of the burnt gases (Fig. 42), so that, at the end of each explosion-stroke, the special piston composed of three parts first opens short slots, whereby the pressure of the gases is equalized to that of the atmosphere,

and only afterwards is the outlet-valve allowed to open. It is clear, without further comment, that by this means the outlet-valve is released before lifting, and that the exhaust-valve chamber and the piping connected therewith are no longer exposed to such high temperature.

It appears to me to be doubtful, however, whether, in the first place, the outlet-valve can really be made much smaller in the

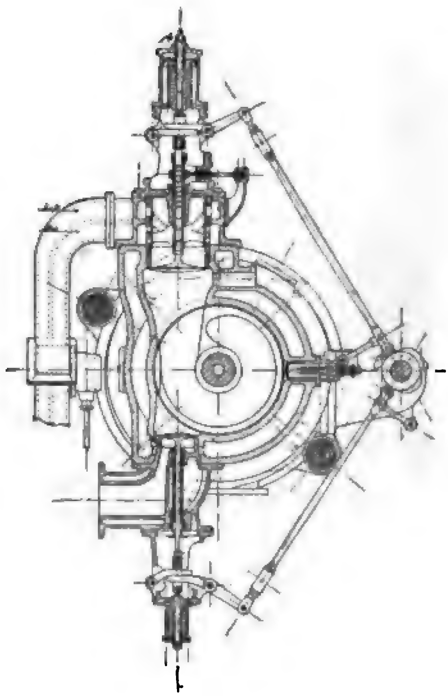


FIG. 41.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF THE DUISBURGER MASCHINENBAU-AKTIENGESELLSCHAFT.

manner claimed by the builders, without causing a too high back-pressure during the whole length of the exhaust-stroke; and whether, secondly, it is not necessary, also, to cool the outlet-valves in larger engines; because if the gases passing through the outlet-valve are no longer so hot as with other four-cycle engines, yet this valve is situated in the explosion-chamber, without, as is the case with the inlet-valve, being cooled by the fresh entering mixture.

The distance between the outer piston-ends must be equal to

the stroke of the engine, and for this reason the engine must be considerably longer than the first described four-cycle engines.

The idea of exhaust slots or ports controlled by the piston in four-cycle engines is not new, since it has been taken into consideration by most builders of the newer type.

The valves are operated by cams with the aid of roller-levers, and the method of governing is by quality. The quantity method could not be employed, because with a light load, com-

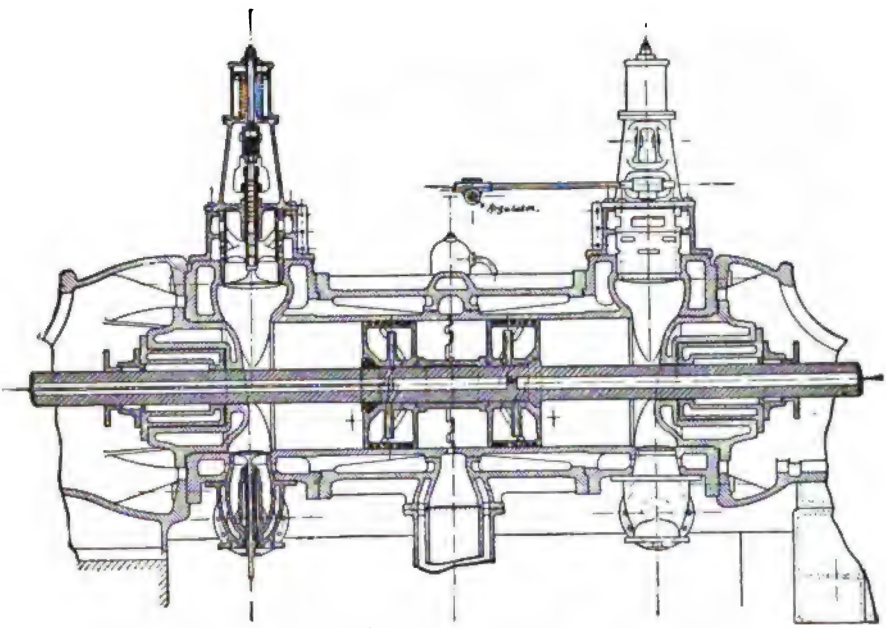


FIG. 42.—DOUBLE-ACTING FOUR-CYCLE ENGINE OF THE DUISBURGER MASCHINENBAU-AKTIENGESELLSCHAFT.

bined with a corresponding back-pressure in the cylinder towards the end of the suction-stroke, it would cause too large a return flow from the exhaust-pipe through the slots.

According to the builders, the combustion, in spite of the quality governing, is complete at all loads. They attribute this to the peculiar form of the combustion-chamber, which should bring it about, that after ignition the portions of the charge that are not yet burning are put into motion and are directed into paths which lead to the portions which are already burning.

As may be seen from Fig. 42, the cylinder consists of three principal parts, an outer jacket strongly held in the middle, in which from both sides a liner, cast in one piece with the valve-chamber facings and a strong flange for bolting to the jacket, is inserted, so that the two cylinder liners meet with a small clearance in the exhaust slots. In the longitudinal axis of the jacket for this reason no tensile or compressive stresses can appear.

11. *Double-Acting Four-Cycle Engine by the Dingler'sche Maschinenfabrik A. G., Zweibrücken.* (Figs. 43, 44, 45, and Plate X.)

The Dingler construction differs from the former other modern four-cycle engines principally in the retaining of a cylinder open at one end. Double-acting is not arrived at in one cylinder, but properly in two single-acting cylinders, whose compression-chambers are bolted together (Fig. 43). Thereby the cylinder-ends, which contain the valves in their outer and inner casing, and as a continuation of the latter, are cast together with the liner, and this is inserted into an outer jacket in such a manner that opposing stresses are avoided. Towards the crank-shaft bearing, this outer jacket continues in the form of crosshead guides and frame.

Both pistons are on the same piston-rod, which must traverse the cooled distance-piece between the compression-chambers through packings. This packing appears to me to be a very difficult detail of the Dingler engine; moreover, if it is an advantage that the tightness of the working-piston can, at any time, be examined and adjusted, by reason of the cylinder being open; this, however, is impossible with the arrangement of the rod. It will be seen from Fig. 43 that at the moment in which the explosion takes place on one side of the distance-piece, the packing-rings are at the other end of the same, therefore the hot gases can penetrate to nearly the whole length of the bush. Consequently, the lubrication is very much affected.

The manner in which the piston is fastened to its rod is peculiar.

A split collar is provided with a series of projections on its inner surface. These projections engage similar parallel grooves that have been turned on the rod.

This collar is covered by a cylindrical sleeve, which has an outside flange to attach to the piston-face, and an inside flange to pull upon the collar. On screwing up the outside flange to

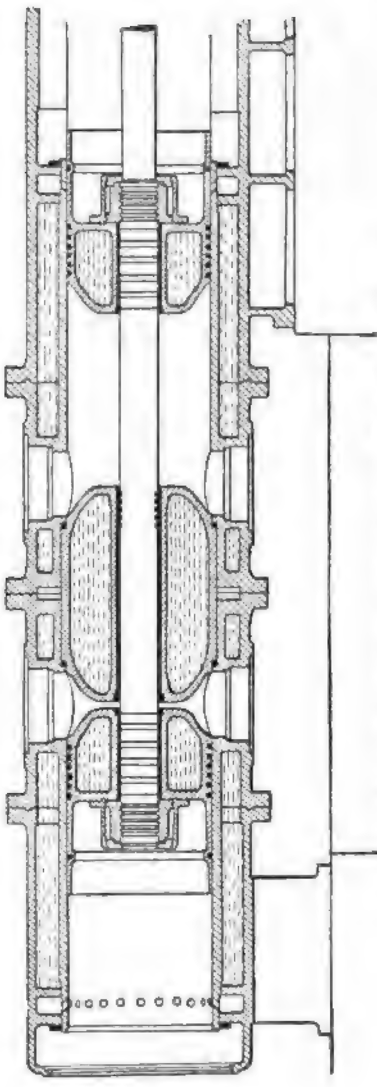


Fig. 43.—The Dingler Double-Acting Four-Cycle Engine.

the piston-face, the collar-projections tighten upon the back face of the grooves, thus putting the piston-rod in tension, and rigidly fixing it to the piston.

The advantage of this method of fastening is the facility with

which it can be disconnected. A number of spring rings are inserted between the rod and a bush placed in the boss of the piston, to make a gas-tight joint against the pressure in the cylinder. The valve-gearing actuates in each case an inlet-valve situated at the top and an outlet-valve situated at the bottom of the cylinder, whose motion is obtained from a common cam on the shaft, a. A second shaft, b, is placed in front of the shaft, a, which rotates with the same number of revolutions as the crank-shaft, and carries an adjustable regulating-cam controlled by a Dörfel flat governor. The action of the adjustable cam,

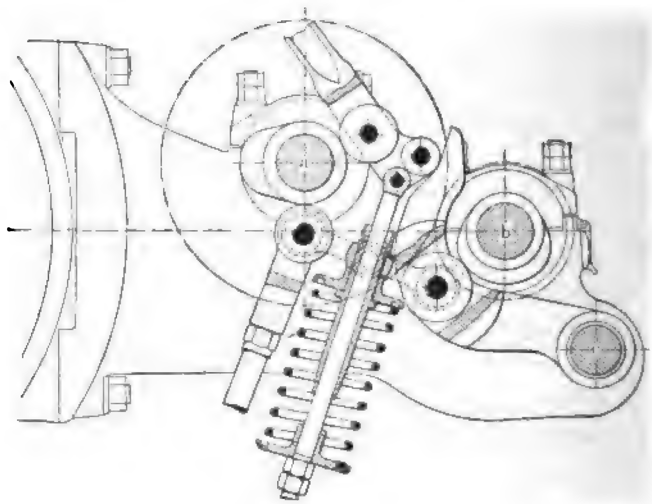


FIG. 44.—THE DINGLER DOUBLE-ACTING FOUR-CYCLE ENGINE.

by a lever moving round the point, c, gives a very equal opening of the inlet-valve for all loads, while the lift and duration of the opening of the mixture-valve are variable. The governing is, therefore, a quantity governing with throttled mixture. The ignition is also adjusted by the governor.

The outlet-valve is not as accessible as it should be.

The engine constructed according to Dingler's arrangement is only slightly longer than double-acting engines with closed cylinders; its advantages consisting above all in the ease with which the piston is taken off.

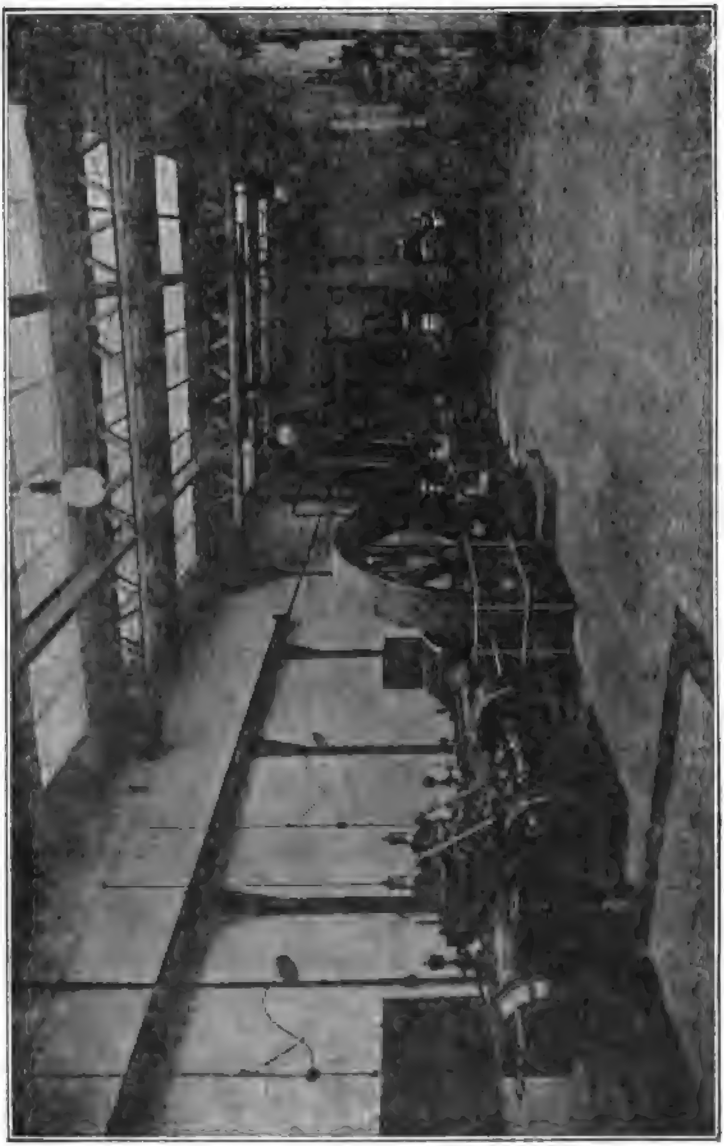


FIG. 45.—THE DINGLER DOUBLE-ACTING FOUR-CYCLE ENGINE.

In Germany the only two-cycle engines to be taken into consideration are the Oechelhäuser system and that of Körting.

The first is represented by the engines constructed by the Ascherslebener Maschinenbau-Akt.-Ges. and by A. Borsig, Berlin, the latter engines by Körting Brothers themselves and their concessionaires, who are: Gutehoffnungshütte, Oberhausen, Donnersmarckhütte, Zabrze, Siegener Maschinenbau-Aktiengesellschaft, and Maschinenbau-Aktiengesellschaft, formerly Klein Brothers, Dahlbruch.

12. *Two-Cycle Engine, Oechelhäuser System.* (Plates XI., XII., and Figs. 46, 47, 48.)

I assume that the manner of working and the advantages of these engines are known. They depend upon the use of the open cylinders and of inlet- and outlet-ports automatically controlled by the working-piston, avoiding the exposure of valve-heads and valves and also of stuffing-boxes and piston-rods to contact with fire; the balancing of the masses and the disappearance of the stress of the frame and foundation; so far a blowing-cylinder is not arranged tandem with the main cylinder. The design can be seen from the drawings of the Ascherslebener Maschinenbau-Aktiengesellschaft (Plate XI.) and of the A. Borsig engines (Plate XII.)

As compared with former examples of the Oechelhäuser engine, the principal modifications are to be found in the formation of the mixture and the manner of governing.

The charging-pump, which is usually placed behind the gas-cylinder, consists of a cylinder with automatic valves, the piston of which compresses, on the one side, gas, and on the other side air, to the necessary charging-pressure.

The scavenging and charging of the working-cylinder takes place during and shortly after the air-compression stroke of the charging-pump, so that air enters through the first open ports in the working-cylinder, and after the piston has overrun the gas-inlet ports an equalization of pressure in the charge-holders and pipes takes place and causes, at a definite moment, air and gas to enter together.

The mixture is thereby formed after the admission of air and gas in the cylinder itself.

The regulation of the speed—that is, the variation of the

charge corresponding to the load by the governor—is arranged differently by the two firms.

In engines by the Aschersleben Maschinenbau-A.G., the admission of gas only is regulated by the governor, and by means of König's patent return-valve, which puts the chamber situated around the gas-ports—that is, the pressure-vessel for the gas compressed in the charging-pump—in communication with the gas-suction pipe of the charging-pump, for a longer or shorter period at each revolution of the engine (Fig. 46).

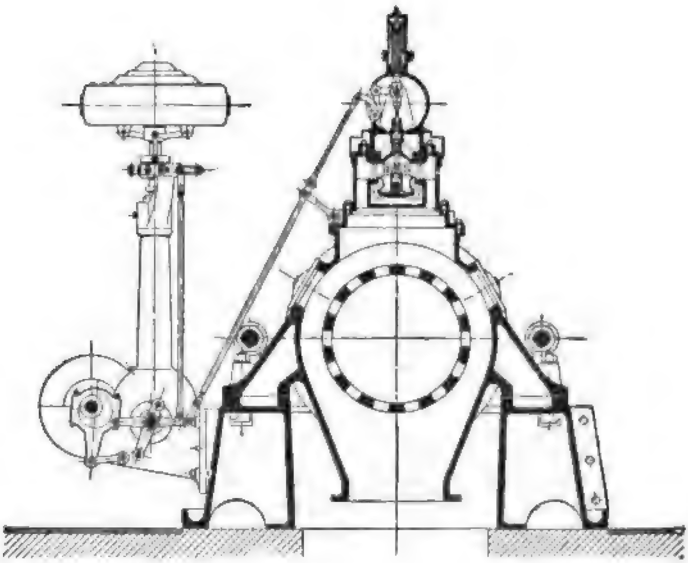


FIG. 46.—THE ASCHERSLEBENER TWO-CYCLE ENGINE.

For all loads the same quantity of air is employed, and the quantity of gas and the time of admission are varied according to the load.

If the return-valve is so regulated that when the gas-ports are opened by the working-piston, it is immediately closed, no gas or mixture can pass over in the gas-return pipe. During the simultaneous admission of gas and air, both are at the same pressure; nevertheless, only a variable mixture can be formed, because during formation the area of the air-inlet is constant, but that for the admission of the gas varies continuously. The governing of the Aschersleben engine resembles approximately

the quality method in four-cycle motors. It gives a variable mixture, and, when running without load, a weak mixture.

Nevertheless, according to information received from the firm, engines governed in this manner, which are coupled to alternating-current electric generators, can be connected in parallel without difficulty.

The method of governing employed by A. Borsig differs from that described above, in that—(1) the quantity both of gas and of air admitted to the working-cylinder is controlled by a return-flow valve, each valve being actuated by a Neuhaus-Hochwald gear. These valves are placed below the engine floor, and are situated in front of the engine, in the gas- and air-mains (Fig. 47). Further, the air admitted is divided by throttling into air for scavenging and for the mixture. (2) A circular valve or sleeve encircles the admission-passages (Fig. 47), which with a diminishing load, and also when the engine is running without load, gradually closes the openings situated opposite the point of ignition, so that when running without load there are only a few openings for the admission of gas where the ignition takes place. This circular valve is moved by gearing controlled by the governor, and represents an indirect method of governing, the disadvantages of which are known, and in this connection could only be ascertained by experiment.

A. Borsig states that a simultaneous variation, in this manner, of the quantities of air and gas and of the areas of the inlet-passages was found to be necessary, otherwise the quantity of gas admitted to the cylinder in proportion to the quantity of air, when the engine was working almost without load, was so small that, when it was distributed throughout, the whole volume was incapable of forming a mixture strong enough to be ignited.

The experience gained by the Aschersleben Maschinenbau-A. G. and by A. Borsig with reference to the governing is of such a contradictory nature that, to those unacquainted with the subject, it would appear to be unintelligible.

It must here be mentioned that in engines up to 1,000 effective h.p. in a single cylinder, A. Borsig arranges one charging-pump, which is placed in the axis of the working-cylinder, but, for powers above 1,000 h.p. in one cylinder, employs two double-

acting charging-pumps for gas and air, driven by one piston-rod, and situated below the floor of the engine-house.

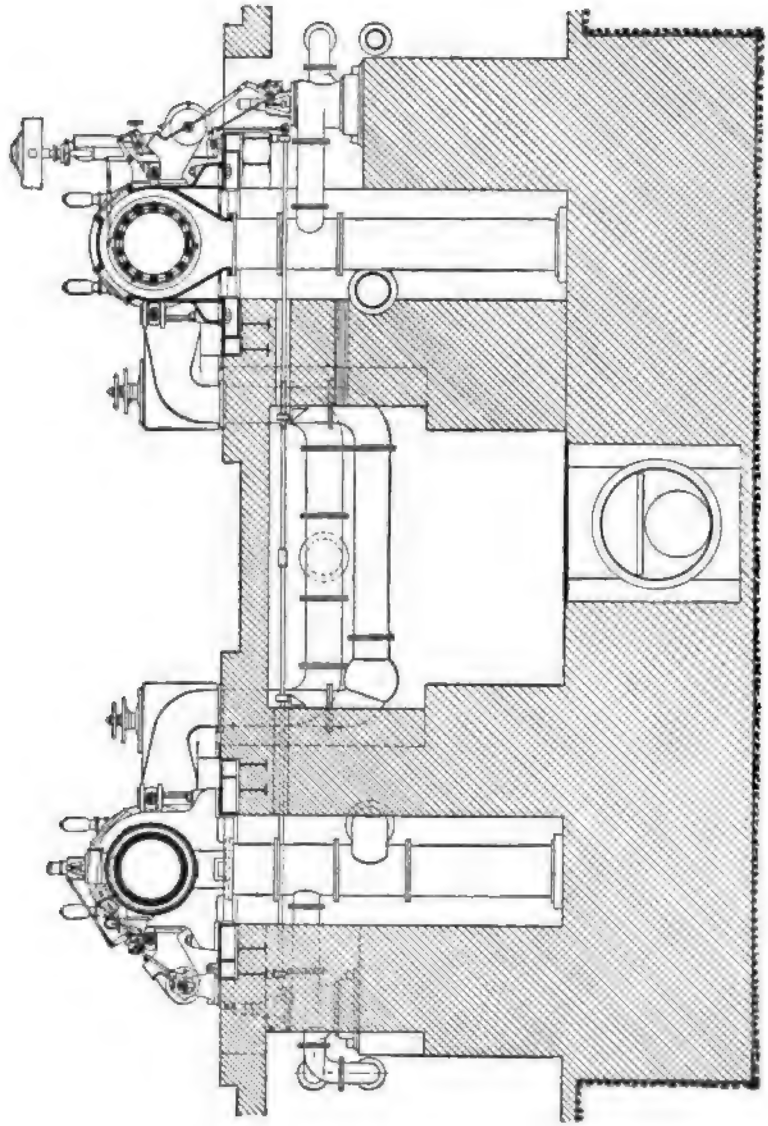


FIG. 47.—THE BORSIG TWO-CYCLE ENGINE.

As compared with former types, the Oechelhäuser engine as now constructed is much narrower, owing to the disappearance of the superfluous outside bearings for the fly-wheel.

13. *Double-Acting Two-Cycle Engine by Körting Brothers.* (Figs. 49, 64, Plates XIII., XIV., and XV.)

The innovations which the above-named builders of Körting engines have introduced in the last few years, consist in the

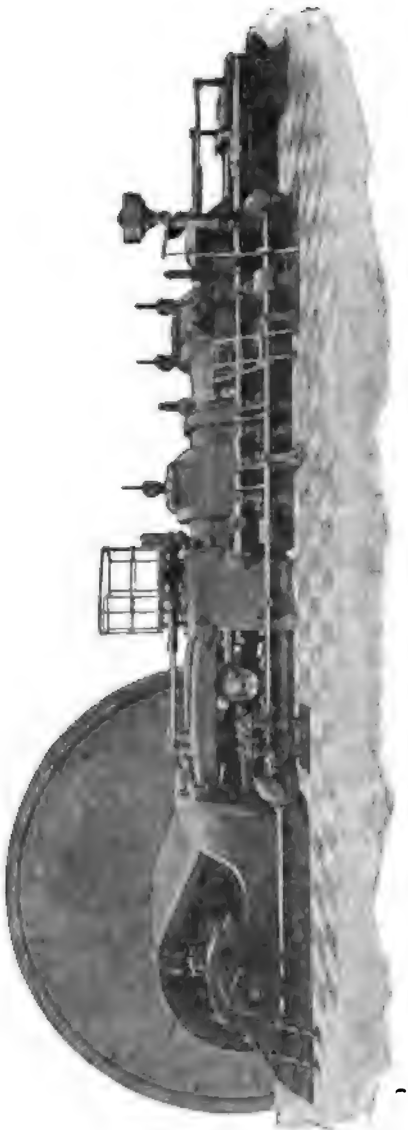


FIG. 48.—THE OECHELHÄUSER TWO-CYCLE ENGINE.

satisfactory design of several parts, principally of the cylinder-heads and of the cylinder; also the simplification of the charging-pump, and improved methods of governing.

The double-acting in the Körting engine takes place on both sides of a piston, in a cylinder whose ends are closed by cylinder-heads. The piston automatically regulates the exhaust-ports, while the inlet of the air and the mixture takes place through an admission-valve situated in the upper portion of the cylinder-head. The cylinder itself stands on two side frames, which, continued forward, form the crank-shaft frames. Between these side-frames the flat crosshead-guide is arranged (Fig. 49, and Plate XV.).

Two separate double-acting charging-pumps, one for air and one for gas, are situated at the side of the working-cylinder.

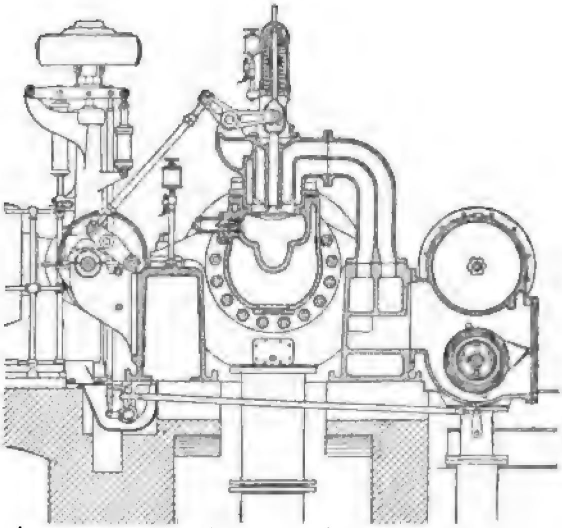


FIG. 49.—ARRANGEMENT OF CROSSHEAD-GUIDE IN THE KÖRTING ENGINE.

I have described elsewhere the principle on which these pumps work.[16]

From these pumps the air and the gas pressure-pipes lead into two concentric circular chambers above the inlet-valve, and as these chambers are constantly in communication with one another, the gas and air are always at the same pressure in the admission-passages.

According to the quantity of gas required, by the action of the governor, air, compressed to the charging-pressure, and always in equal quantity, enters from the circular air-chamber,

[16] *Stahl und Eisen*, vol. xxii., pp. 1157 to 1182 (1902).

and for some distance into the gas-passage, so that, at a definite moment depending on the load, when the inlet-valve is opened, air first, and then gas and air, enter the working-cylinder together at the same pressure, but in quantities proportional to the respective areas of the air- and gas-pistons of the charging-pumps, until the inlet-valve closes.

The formation of the mixture, as described, is ideal, and cannot be surpassed, for an entirely constant quantity is formed, with the proportion of gas and air as intended by the design,

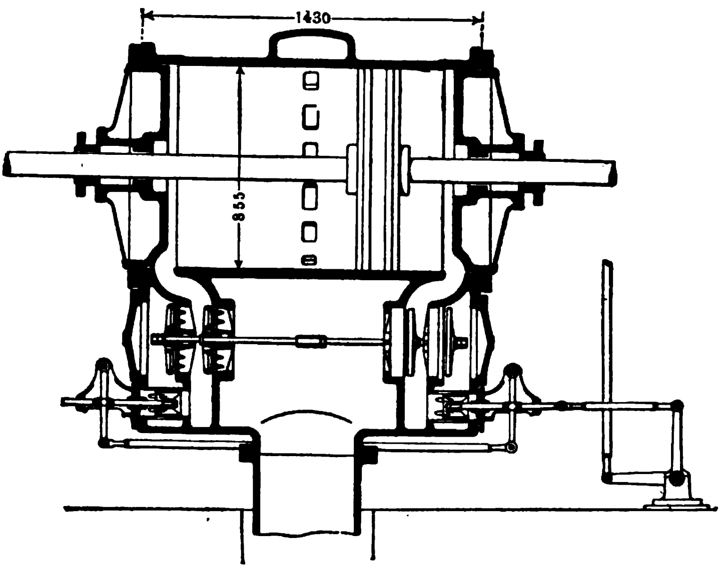


FIG. 50.—CHARGING-PUMP BY KLEIN BROTHERS.

and entirely independent of the pressure, or of the variation of pressure in the suction-pipes of the charging-pumps. In the Körting engines these variations of pressure, in reality, have no influence on the working of the motor, at least only to a slight degree at the time when the engine is working at full load.

At all loads and speeds of the engine a good mixture is always to be found, after compression, next to the ignition-point.

The compression varies with the load, while the quantity of air admitted is constant, and the quantity of gas is reduced with the load.

The inlet-valve is controlled by cams, and in most cases closed by springs. Considerable acceleration-resistances are caused by the rapid opening and closing of the valves, and for this reason the gearing for closing the valves should also be arranged with cams and roller-levers.

To govern the speed of the engine—that is, to regulate the admission of gas, with corresponding loads—the Körting engine was originally fitted with a governor with a return-flow valve, in such a manner that a throttle-valve, controlled by the governor, allowed more or less gas to return to the cylinder of the charging-pump from the gas-pressure passage (between the cylinder and the charging-pumps), during the period of suction.

Though this system of governing makes extra work for the gas-pump, it is, even in the latter types of Körting engines, still employed, owing to its simplicity, as shown by the charging-pump by Klein Brothers (Fig. 50).

The charging-pumps were originally worked by an eccentric valve-motion with a circular valve, both for inlet and outlet.

In more modern engines the charging-pumps have direct-acting piston slide-valves for the inlet-valves and also for the outlet (Plate XV.), and by adjusting a double slide-valve motion, the quantity of gas can, at the same time, be regulated.

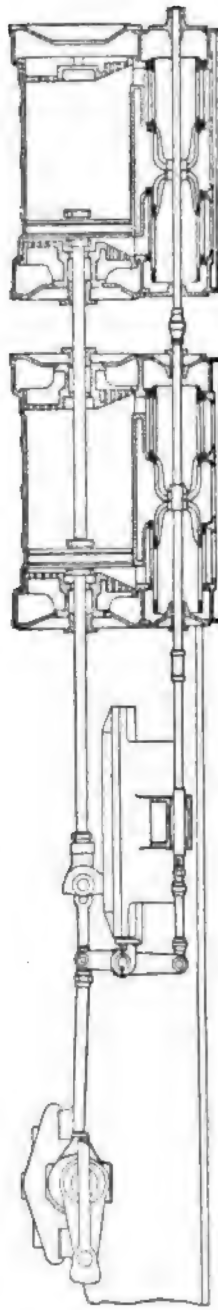


FIG. 51.—CHARGING-PUMP GEARING OF THE SIEGENER MASCHINENBAU-AKTIEN-GESELLSCHAFT.

The charging-pumps manufactured by Klein Brothers and the Siegener Maschinenbau Company are much more simple. The first have no eccentric valve-motion,

but only automatic valves (Fig. 50). In this pump Klein Brothers have taken advantage of the peculiarity of the Körting engine—namely, that the air-pump compresses during the complete stroke and the gas-pump commences to compress in the middle of the compression-stroke. For this reason the cylinder of the gas-pump is provided in its middle portion with ports, which communicate with the gas-suction. The gas can return to the suction-pipe through these ports during the first half of the compression-stroke. This regulation of the charging-pump avoids the unnecessary consumption of oil and power that obtains in the former slide-valve motion.

The charging-pump gearing of the Siegener-Maschinenbau-Aktien-Gesellschaft is shown in Fig. 51. The eccentric motion is here retained; but a single eccentric with a slide-valve rod moves all the inlet-valves of the gas- and air-pumps. The exhaust-valves of the charging-pumps are placed in the cylinder-covers.

FIG. 52.—CHARGING-PUMP DIAGRAM.

The valves situated under the pump-cylinders are provided with tapered openings, and work in casings with similar openings. When the gas-slide is moved by the action of the governor, the tapered openings of the slide and of the casing are brought nearer to, or farther from, each other. Thereby at the beginning of the suction period a variable "after opening" of 0 to 10 per cent. takes place, and the suction-pipe is closed during the pressure stroke (after an admission of from 35 to 80 per cent.). A diagram from this charging-pump is reproduced in Fig. 52.

The air-pump can be regulated in a similar manner by hand.

This simple motion avoids the return of compressed gases.

With clean gas this motion could probably be actuated by the governor; but if the gas is not very clean, and at the same time is wet, the friction of the throttle-slide and, at times, the resistance of the inlet-valve will be excessive.

In newer Körting engines the liners of the working-cylinders and the jackets are no longer cast in one piece; they are more frequently made in halves, inserted into the jacket, so that the outer and inner cylinder liners can expand independently (Fig. 53).

All builders of the Körting engine have retained the cylinder-heads bolted to the cylinder, and from the modifications, as shown in Fig. 54, as compared to the usual constructions, it may be concluded that they gave trouble by cracking.

The newer designs of the cylinder-heads avoid the pressure of the stuffing-box chamber on the outer wall of the cylinder-head.

The long pistons are cast in one piece, and have either a boss extending throughout their whole length or a short boss at

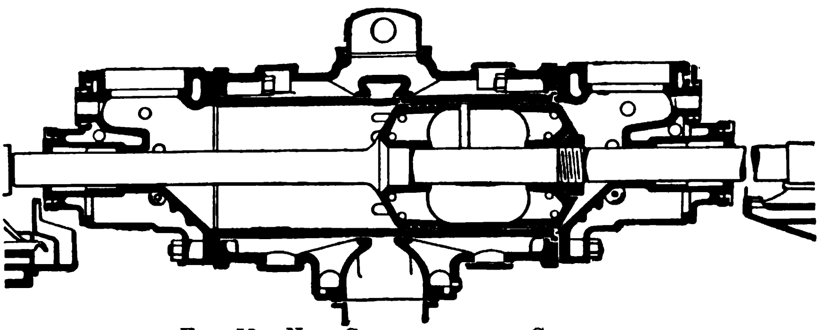


FIG. 53.—NEW CONSTRUCTION OF CYLINDER.

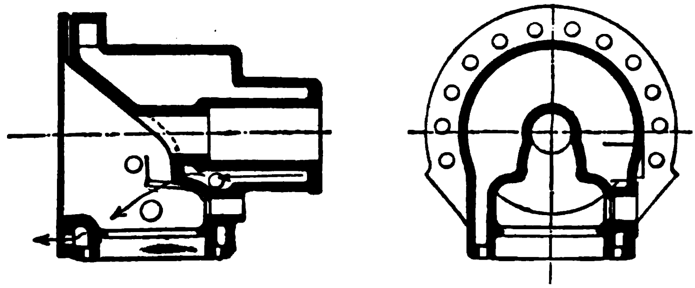
each end. In large engines the pistons are supported by back or front guides; in smaller engines the guide is dispensed with, and in its place the middle of the under surface of the piston is lined with anti-friction metal (Fig. 55).

Fig. 56 shows how the piston can be removed. It will also be noted that the piston-rod can be readily disconnected from the crosshead (Fig. 57).

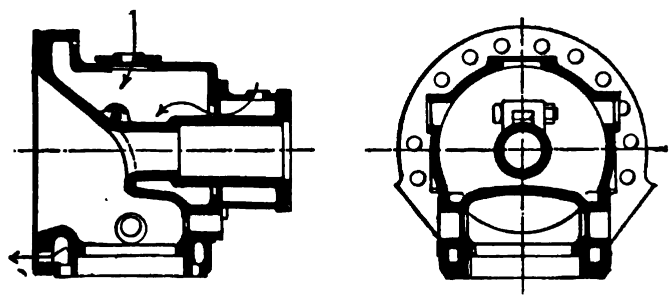
The Körting engine is specially suited for driving blowing-cylinders, because it starts easily when loaded, and is certain in its working at great variations of speed, and moreover when the speed is very low.

Fig. 58 shows the arrangement of the valve-gearing of the Corliss inlet-valves of a blowing-engine constructed by the

Siegener Maschinenbau A.G. In this gear, by means of a link with releasing mechanism, on the one hand, the amount of the



Former.



New.

FIG. 54.—CONSTRUCTION OF CYLINDER-HEAD.

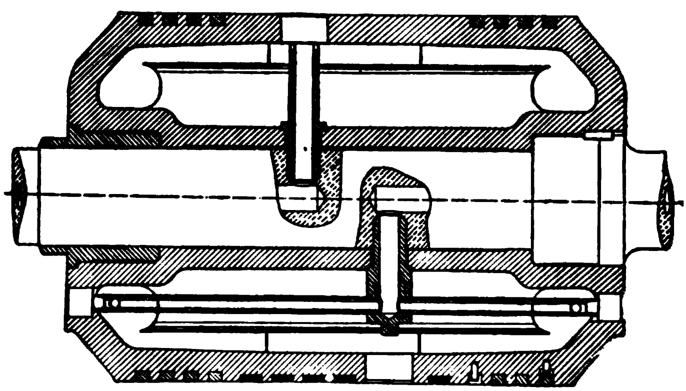


FIG. 55.—PISTON CONSTRUCTION.

lap of the valves, and, on the other hand, the stroke and the advance of the eccentric, can be varied.

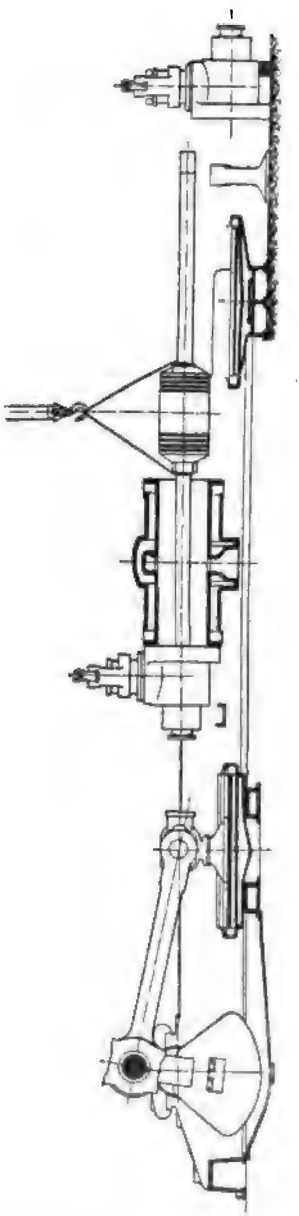


FIG. 56.—METHOD OF REMOVING PISTON.

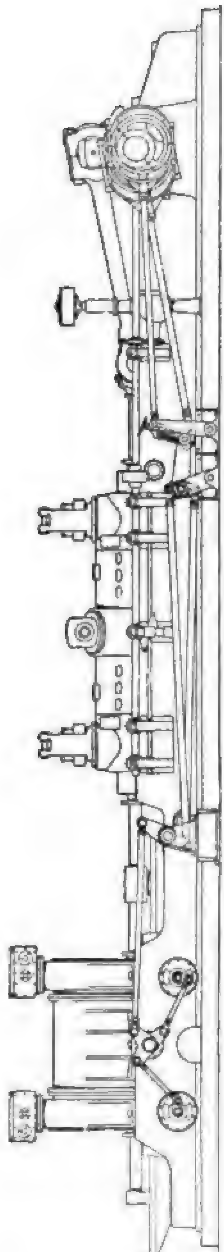


FIG. 58.—BLOWING-ENGINE VALVE-GEAR.

By this means, with an almost constant opening for the admission, the closing of the inlet-valve is brought about, at the commencement of the pressure-stroke at the ordinary load, but when the load is taken off, at the end of the pressure-stroke. Between these limits the variable admission of the blowing-cylinder is arranged for blowing smaller quantities of air at a higher pressure with approximately an equal expenditure of power.

The same object is attained by other builders by arranging return-flow valves on the blowing-cylinder. In this connection, for example, Klein Brothers make the valves in such a manner that they can be controlled by hydraulic pressure from the

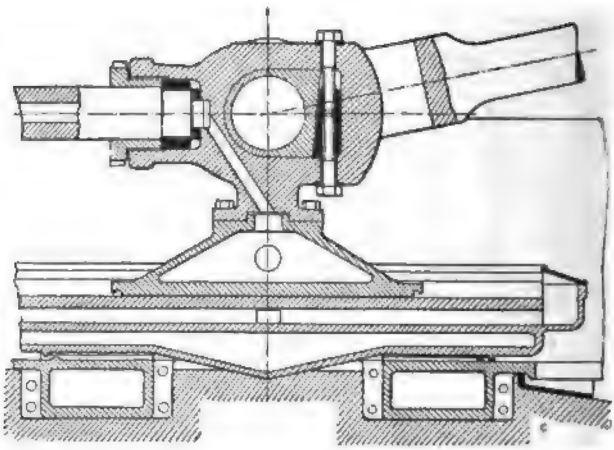


FIG. 57.—CROSSHEAD CONNECTION.

central position occupied by the driver, so that, as with the Siegener arrangement, if a blast-furnace scaffolds, or other similar accidents occur, the blast can be suddenly shut off.

I wish to remark here that most of the ironworks have answered my question as to the most practical size of the engines, viz.: for driving dynamos, from 1,000 to 1,200 b.h.p. per unit; for driving blowing-cylinders, for each blast-furnace a separate engine, usually, say, from 1,000 to 1,200 b.h.p., or in some cases, larger units, say from 1,600 to 3,600 b.h.p., according to the efficiency of the furnace. Concerning the size of the engines, it may be observed that with a few large units, as compared with a larger number of smaller units, the reserve power of the

plant, also the safety of the apparatus—for example, of the pistons and cylinder-covers—diminishes; and further, that the cleaning of the large engines is more complicated and takes more time.

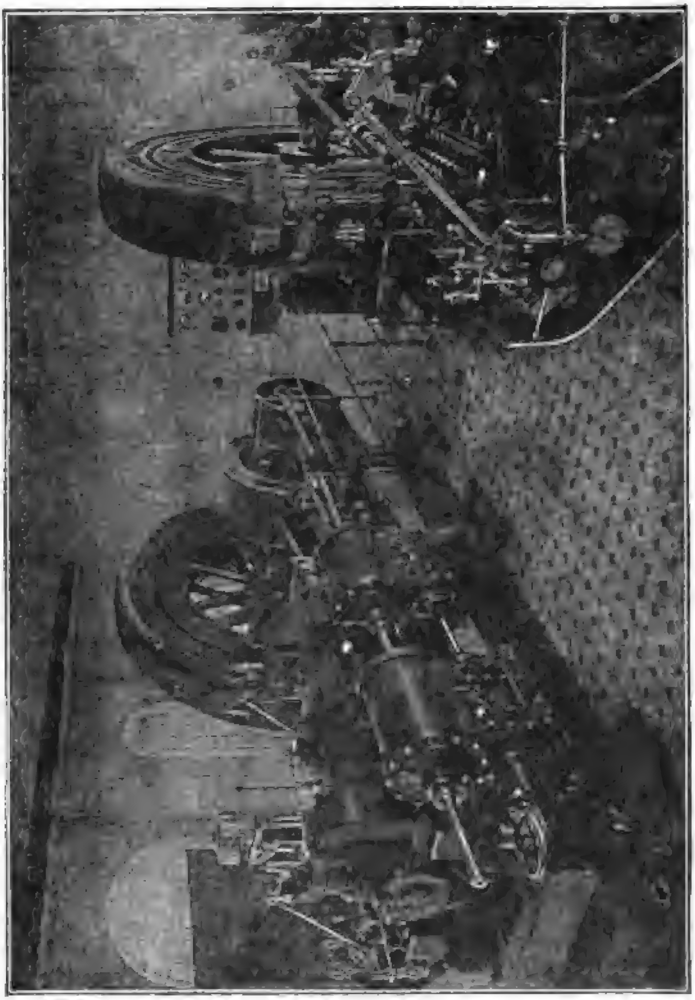


Fig. 59.—Double-Acting Two-Cycle Körting Engine.

Units larger than 1,000 to 1,200 effective h.p. are only to be found in very large plants, or where the space is limited.

From the answers received to my last question concerning the possibility of connecting alternating-current dynamos in parallel, when driven by gas-engines, this, stated generally, can

be done without special difficulty. From several sources it is gathered that sometimes the practice of switching in, at the

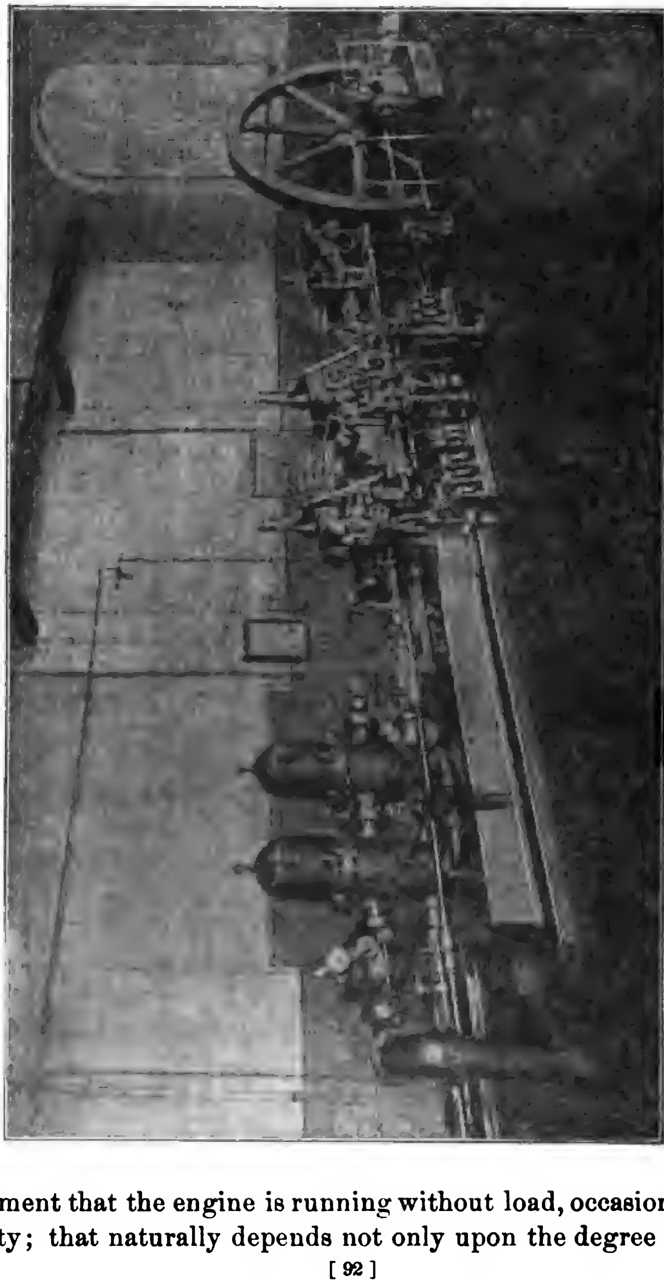


FIG. 60.—DOUBLE-ACTING TWO-CYCLE KÖRTING ENGINE.

moment that the engine is running without load, occasions difficulty; that naturally depends not only upon the degree of uni-

formity of the engine, on the momentum of oscillation of fly-wheel, and on the construction of the dynamo, but above all

FIG. 61.—DOUBLE-ACTING TWO-CYCLE KÖRTING ENGINE.

upon the action of the governor and the formation of the mixture at the time named, and for this reason will vary with the design of valve-gear.

After considering all these various types regarding the question as to which system—two-cycle, or double-acting four-cycle—should be adopted, I wish to make the following statement:

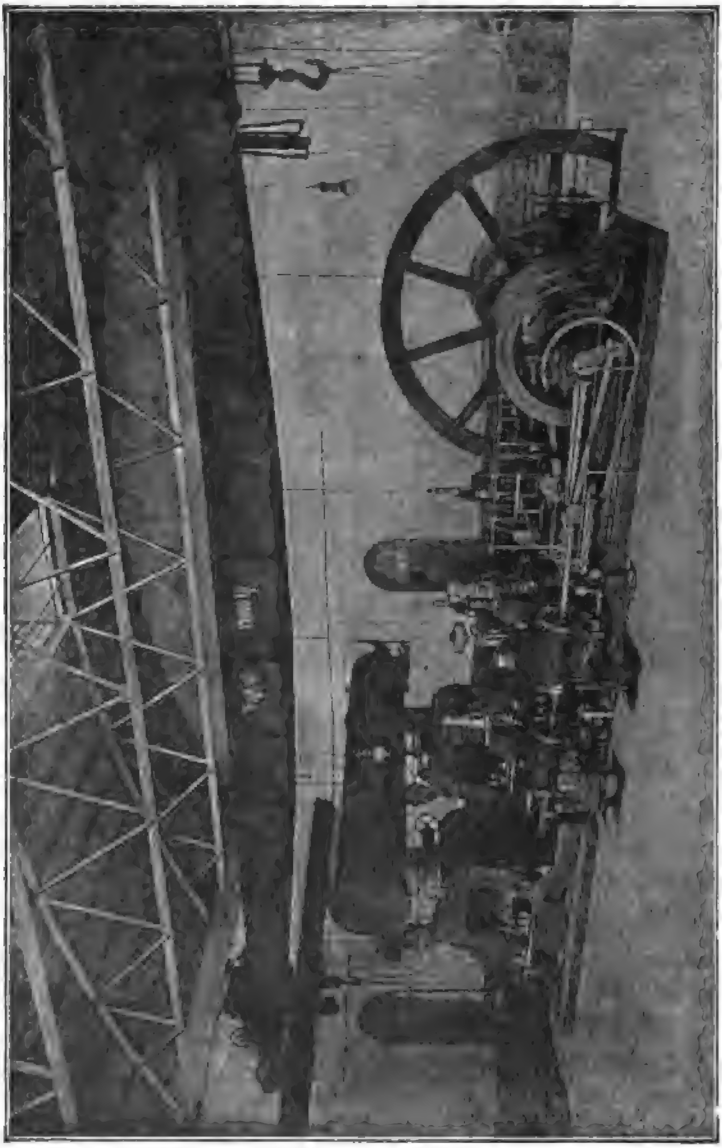


FIG. 62.—DOUBLE-ACTING TWO-CYCLE KÖRTING ENGINE.

When the double-acting two-cycle engine was introduced by Körting Brothers in the year 1902, a number of engines made by them met with general success; this engine, as compared

with the then-existing single-acting four-cycle engines, showed such marked progress in this line that many considered that

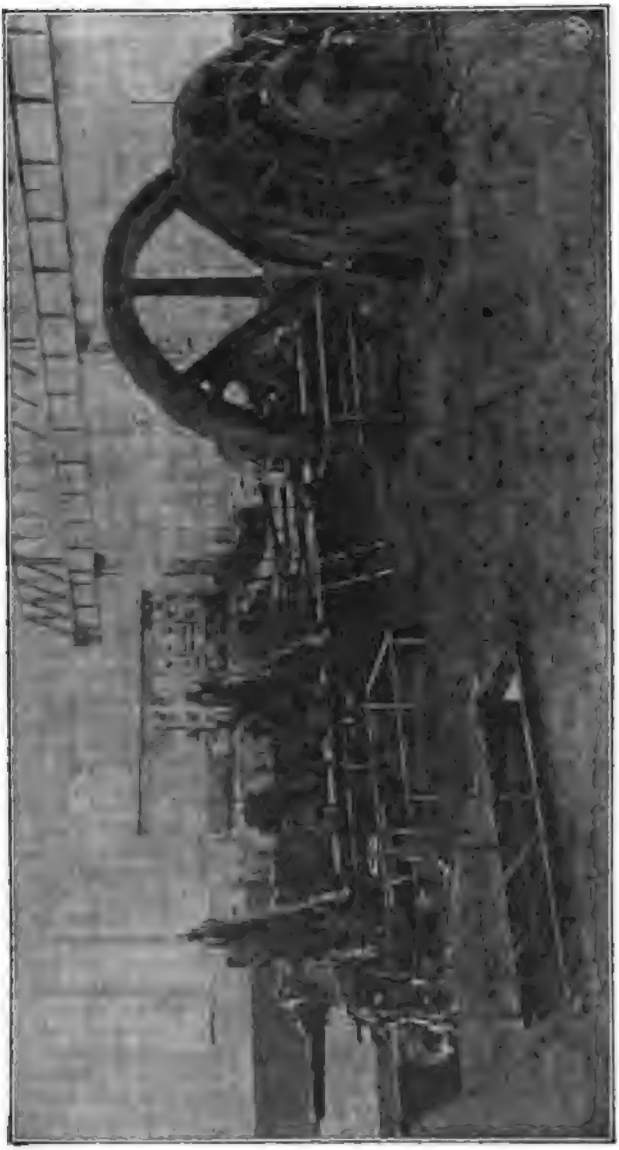


FIG. 63.—DOUBLE-ACTING TWO-CYCLE KÖRTING ENGINE.

the four-cycle system was no longer a serious competitor. The builders of four-cycle motors were, however, guided by the success of the Körting engines in the right direction—namely,

of reconstructing their engines as double-acting engines in a single closed cylinder, and to arrange two of these cylinders, the one behind the other, with the object of increasing the me-

FIG. 64.—DOUBLE-ACTING TWO-CYCLE KÖRTING ENGINE.

chanical duty. Professor Meyer had already at that time called attention to the fact that, in view of the large negative work expended in the charging-pump of the Körting engines,

the double-acting tandem four-cycle engine would, without doubt, again seriously compete with the Körting engine. That this forecast was a correct one, may be seen from the statistics given at the commencement of this paper.

Many persons at the present time, in judging the question of system, go so far as to prophesy that the gas-engine will return to its original starting-point—viz., the four-cycle system—while others, equally convinced, affirm that the four-cycle will not continue to be adopted by ironworks and other manufactories.[17] Even with the experience gained up to the present time, it is impossible to give an opinion, based upon sufficiently trustworthy evidence, in favor of either of these opposing views. It is impossible to come to a conclusion, from the total horse-power without further considering the proportionate value of the two systems; for up to March of this year, engines with 260,000 b.h.p. were at work, or on order, for double-acting four-cycle as against 91,000 for two-cycle. If these figures prove that the competition of the two-cycle engine must not be neglected, on the other hand, the importance and connection of the builders of the four-cycle types must be considered advantageous to the latter.

The builders of two-cycle engines will themselves admit that these motors are less adapted for the high speeds required for driving dynamos than for driving blowing-engines and pumps, because, with a reduced time of charging, the resistance of the charging-pump cannot be kept low enough; and principally, owing to the relatively larger number of explosions (especially with gases of high calorific value, such as coke-oven gas), the flow of heat through the metal walls, and thereby affecting the security of the explosion-chamber against breakage and the occurrence of premature ignitions, create uncertainty; as, moreover, the governing hitherto employed in two-cycle engines for dynamo-driving is, as a rule, inferior to that of the four-cycle engines. For this reason it may be explained that several firms who build two-cycle engines have lately decided to adopt also the manufacture of double-acting four-cycle engines.

On the other hand, the two-cycle engine is, without any

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[17] Güldner, *Entwerfen und Berechnen der Verbrennungsmotoren*, 2nd edition, p. 190.

doubt, most suitable for driving blowing-cylinders; for, as already stated, it permits, within wide limits, a variation in the number of revolutions per minute; it starts easily against a load, and at the low speeds of the blowing-piston the work of the charging-pump is not excessive. Klein Brothers, for instance, state that the work of their charging-pump with valves is from 6 to 7 per cent. of the work of the power-cylinder, so that the difference, compared with the negative work of the four-cycle motor, no longer preponderates.

Theoretical discussions concerning the correct or the incorrect mechanical efficiency, which during last year created such a stir in Germany, can for the present contribute nothing to elucidate the question of the systems. For the managers of works, in addition to inquiring about the price and power of a gas-engine, above all inquire about the security in working, and least of all about the quantity of gas consumed per b.h.p. They do not trouble themselves at all about the mechanical efficiency.

Suitable trials concerning the consumption of gas in more recent engines are not available for comparison, therefore it is not known how far the two-cycle engine is at the present time, in this respect, inferior to the four-cycle engine. Should the ironworks now be compelled to consider an economy of gas, I do not believe that the larger consumption of the two-cycle engines would for long have any great influence on the question of systems; for then the ironworks would probably first consider a more thorough cleaning of the gas employed for heating the blast and for burning under the boilers, thereby increasing its value, and in this manner saving gas. So long as these conditions remain as they are, and so long as the four-cycle engine is not more secure, under average working conditions, than the two-cycle engine, so long will the question of systems not be decided by general and theoretical considerations, but in such cases by the ironworks and mining industries themselves.

The situation was well summed up by a manager who, referring to this very point, told me personally that he himself preferred double-acting four-cycle, but his engine-drivers preferred double-acting two-cycle.

As regards other industries, they need not at present be con-

sidered to such an extent that they could assist in deciding the question.

In conclusion, it is my duty to state that the present position of the application of gas-engines in German ironworks shows the value the managers of these undertakings attribute to the better and less dangerous utilization of the waste gases of their furnaces, and the successful efforts that have been made by the German engineers in order to meet the requirements suddenly demanded by ironworks. It also proves that German ironworks are obliged to utilize to the uttermost the sources of power at their disposal, in order to insure their existence, and their participation in the trade of the markets of the world. In other richer countries, with more favorable conditions, the matter is not so urgent.

PLATES.

SECRETARY'S NOTE.—Plates I. to XV. in the pamphlet edition published by the Iron and Steel Institute were printed on individual inset folders. In the present paper these illustrations have been arranged more conveniently by extension over two opposite pages.—R. W. R.

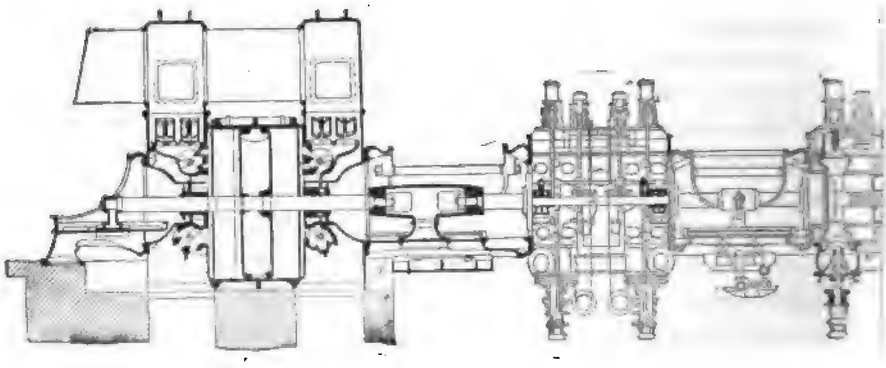


PLATE I.—BLOWING GAS-ENGINE, BY THE

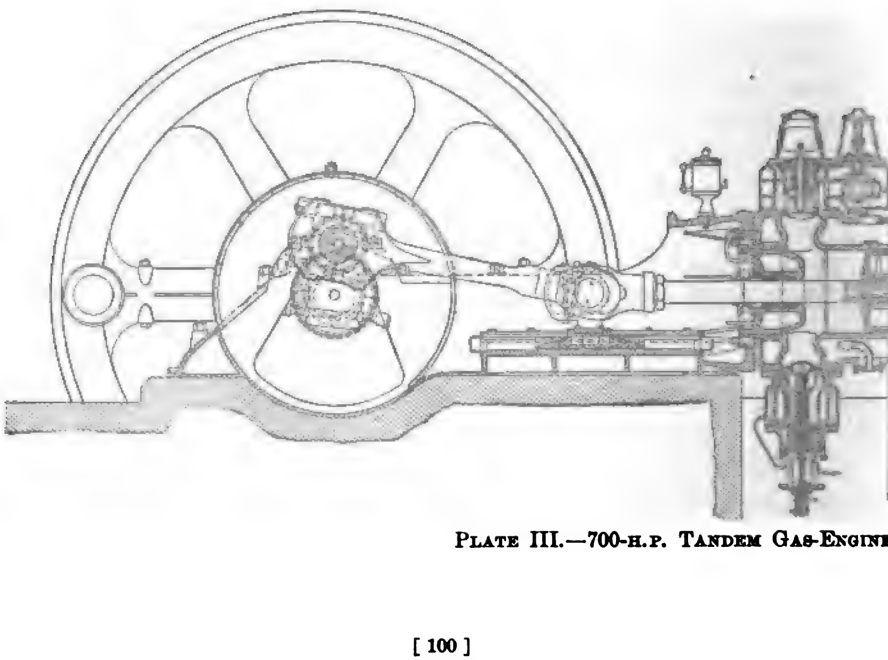
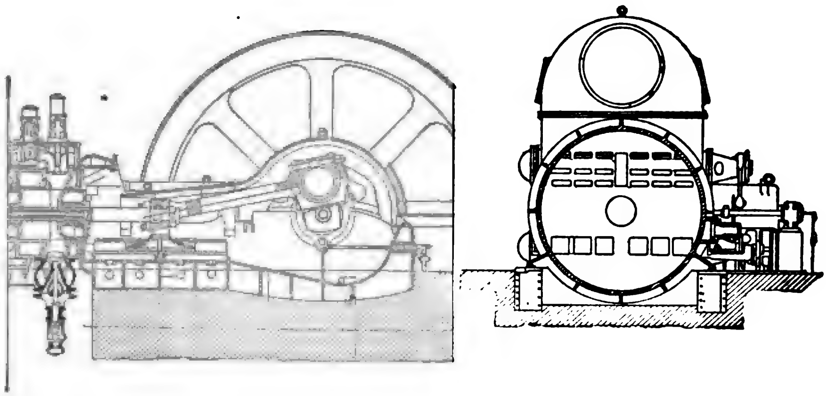
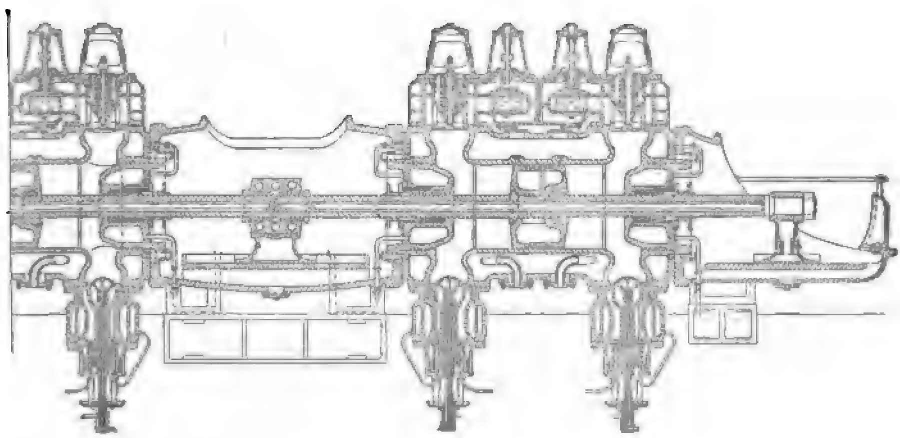


PLATE III.—700-H.P. TANDEM GAS-ENGINE,



MASCHINENBAU-GESELLSCHAFT NÜRNBERG.



BY EHRHARDT & SEHMER.

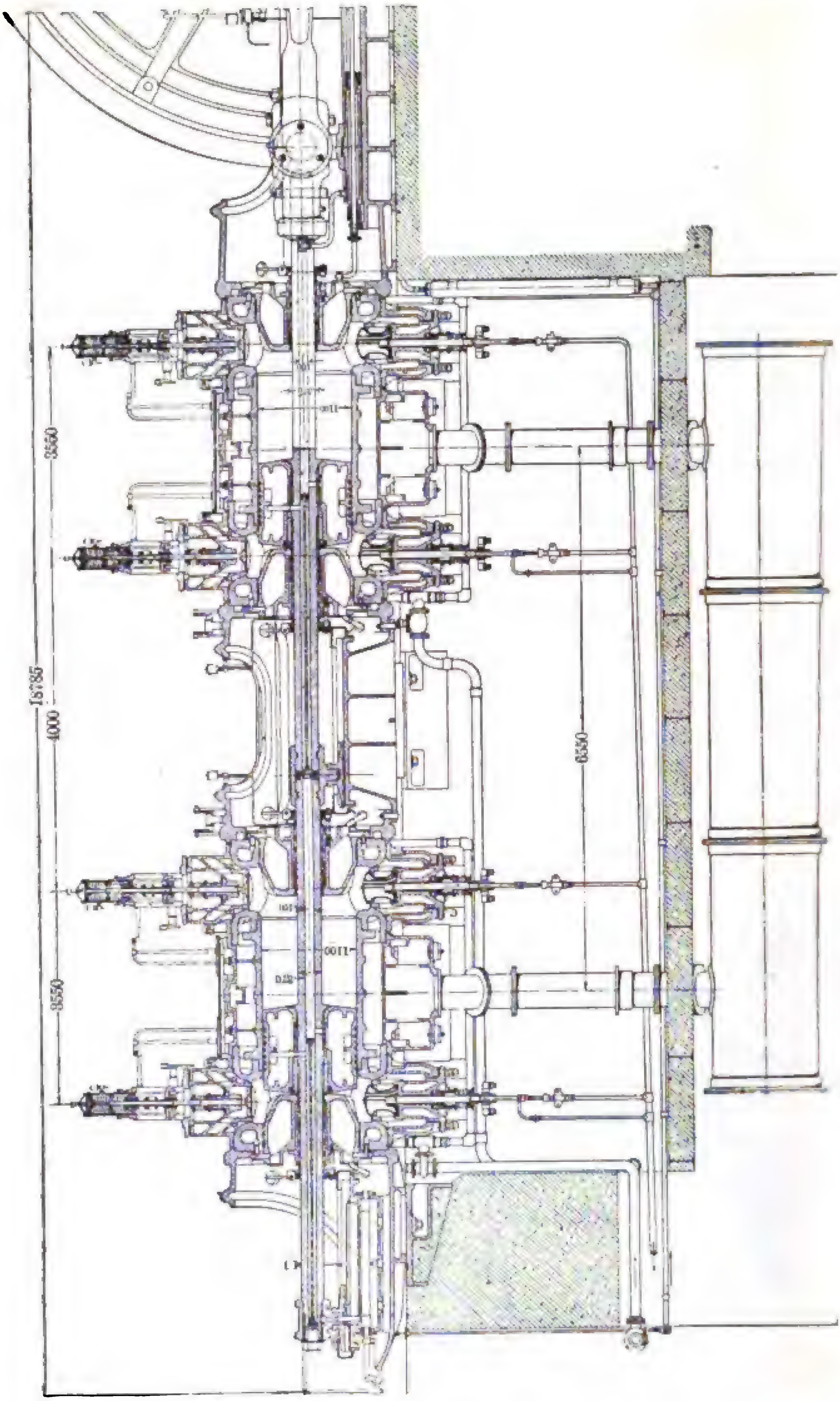


PLATE II.—2,000-H.P. GAS-ENGINE, BY THE GASMOTORENFABRIK DEUTZ.

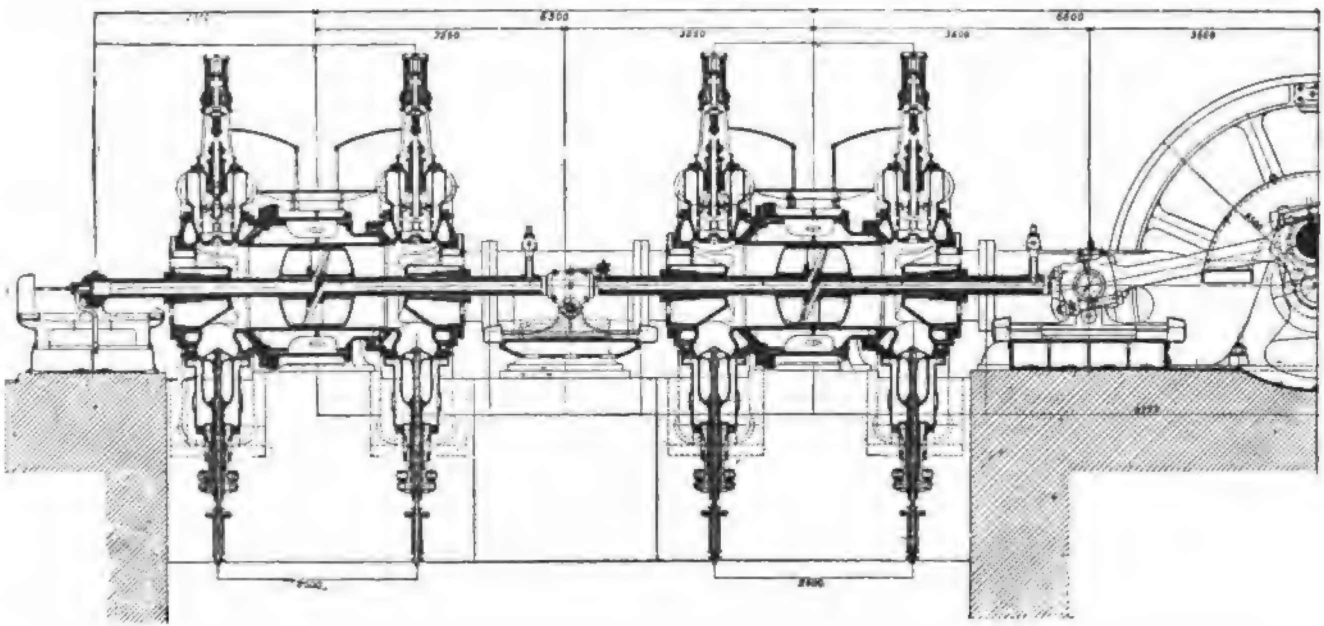


PLATE IV.—1,500-H.P. TANDEM GAS-ENGINE, BY THE MARKISCHE MASCHINENBAUANSTALT. (See also pp. 104 and 105.)

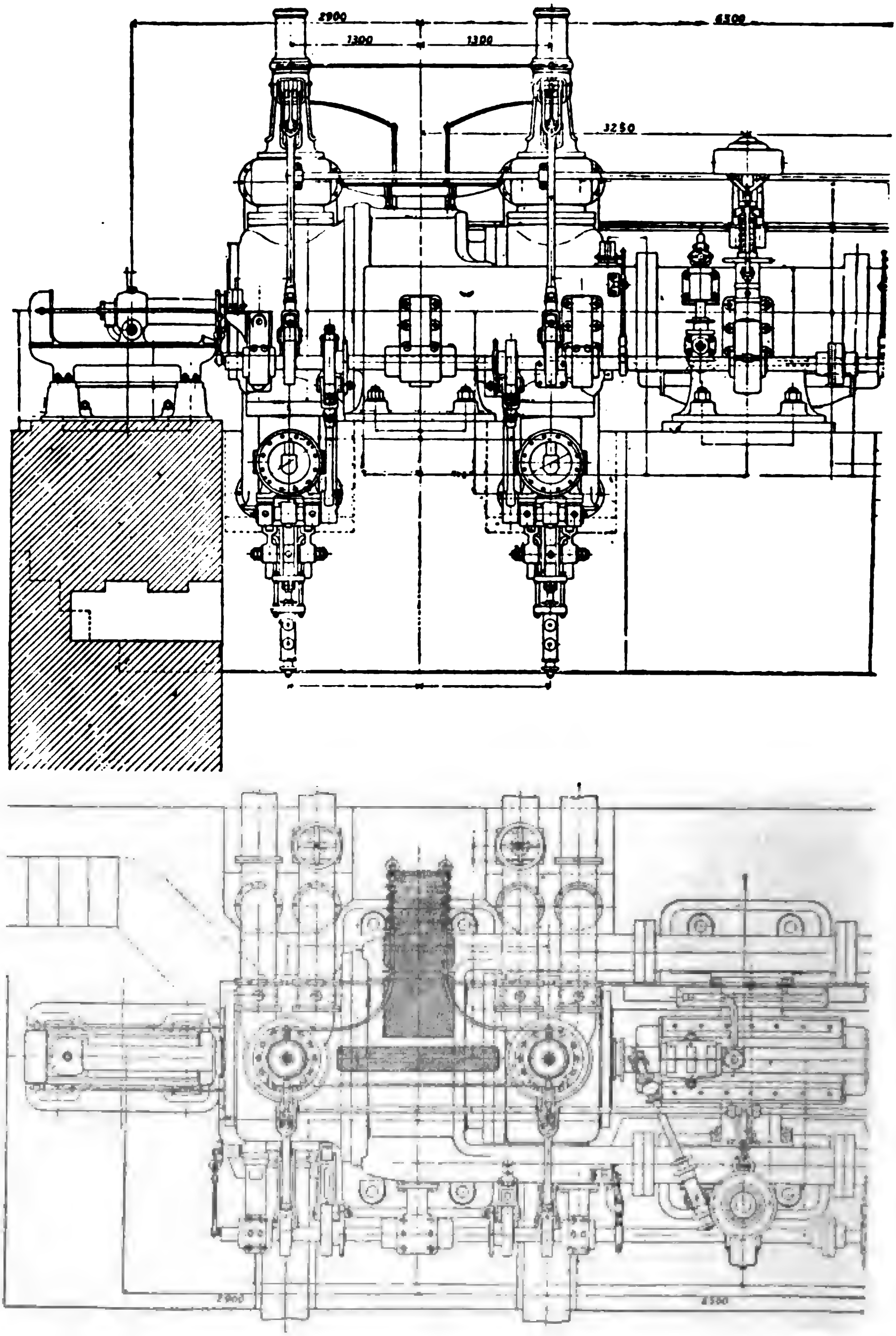
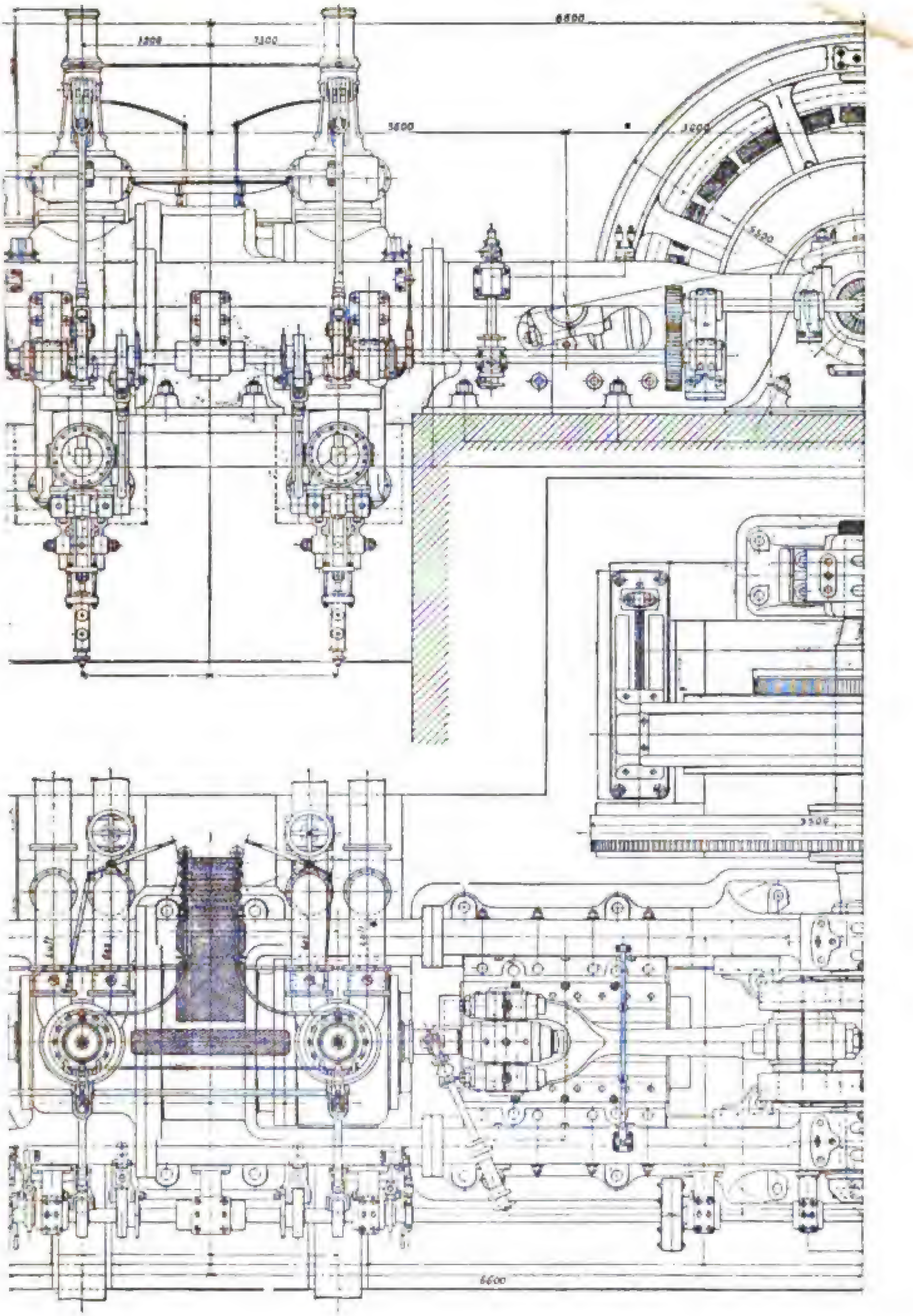


PLATE IV.—1,500-H.P. TANDEM GAS-ENGINE, BY



THE MARKISCHE MASCHINENBAUANSTALT. (See also p. 103.)

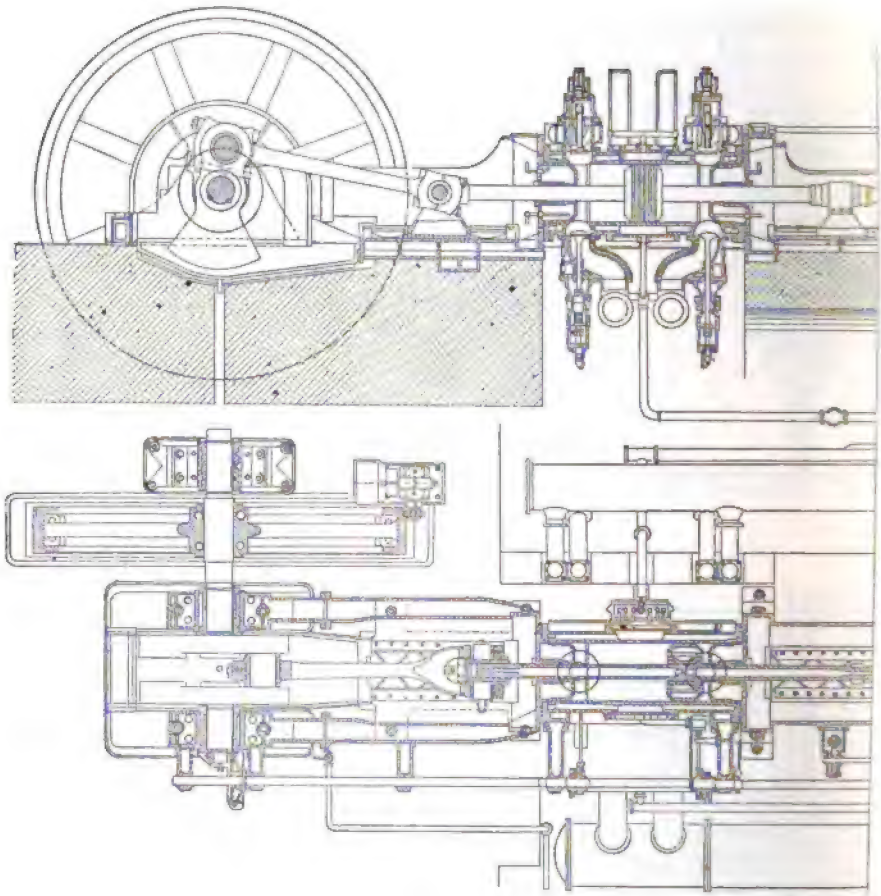
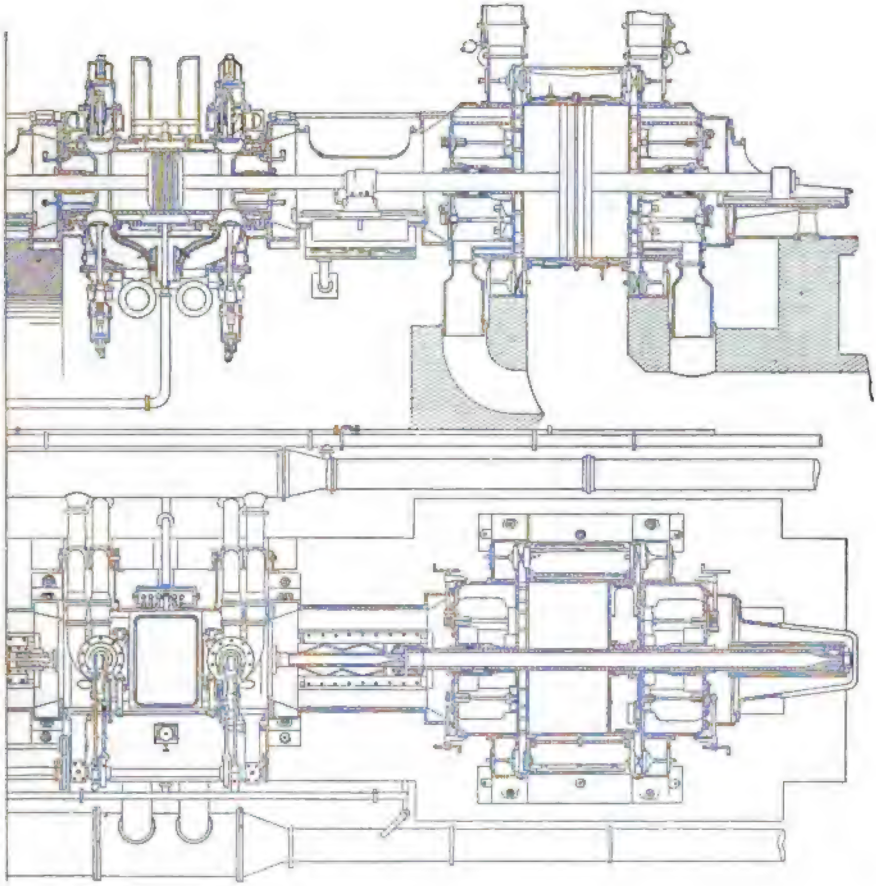


PLATE V.=1,500-H.P. BLOWING GAS-ENGINE,



BY THE ELSÄSSISCHE MASCHINENBAUGESELLSCHAFT.

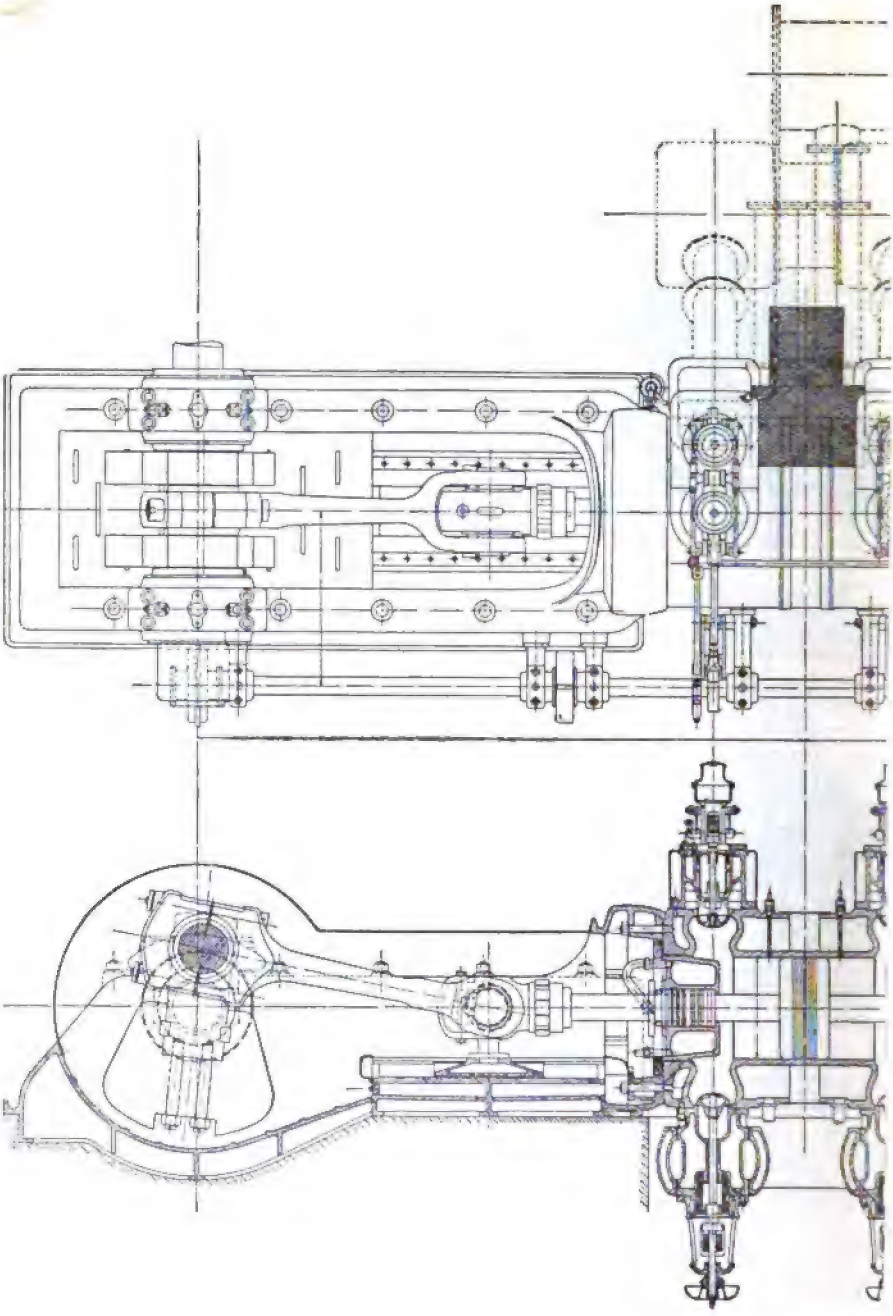
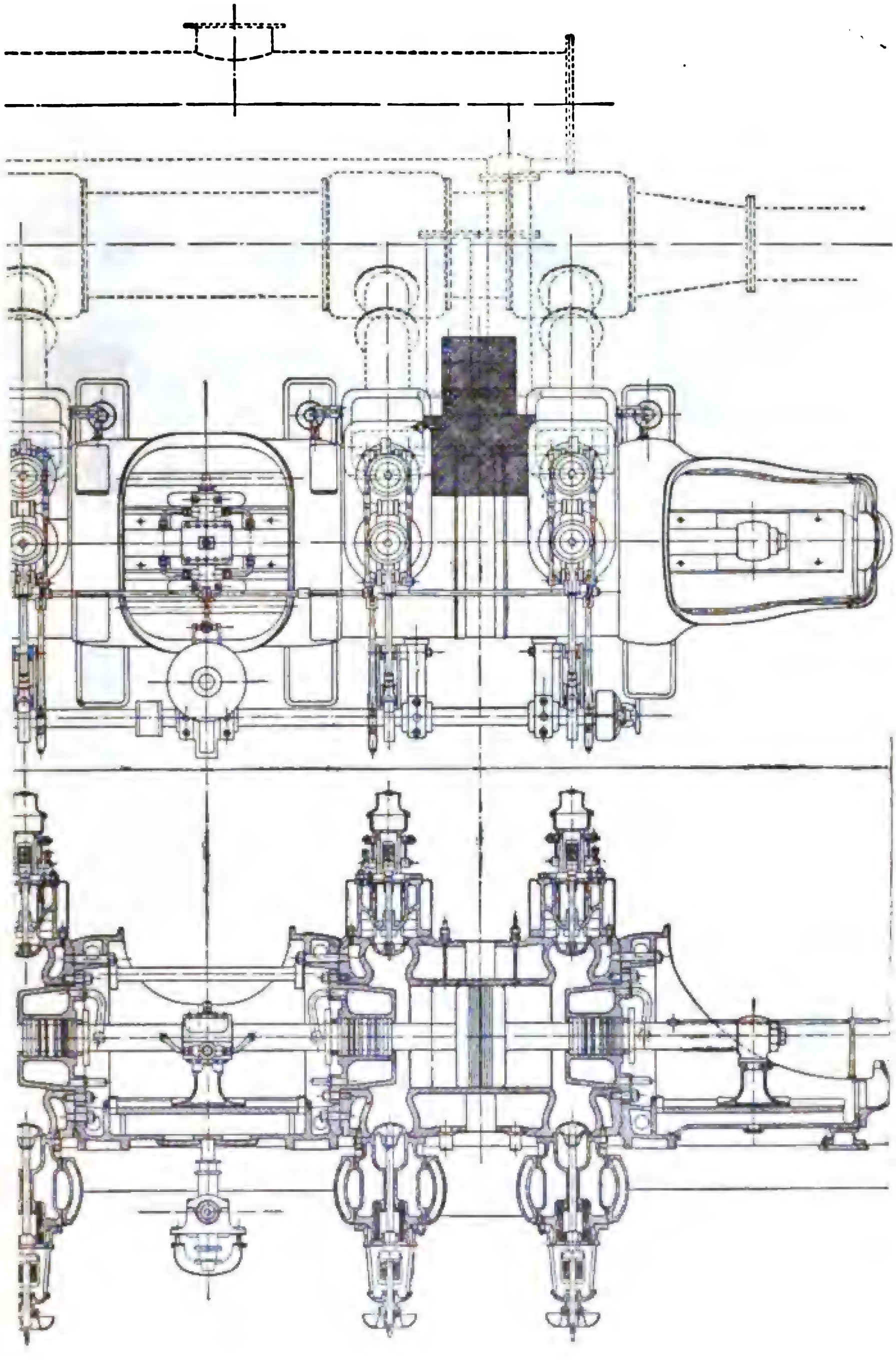


PLATE VI.— TANDEM GAS-ENGINE, BY



THE GUTEHOFFNUNGSHÜTTE.

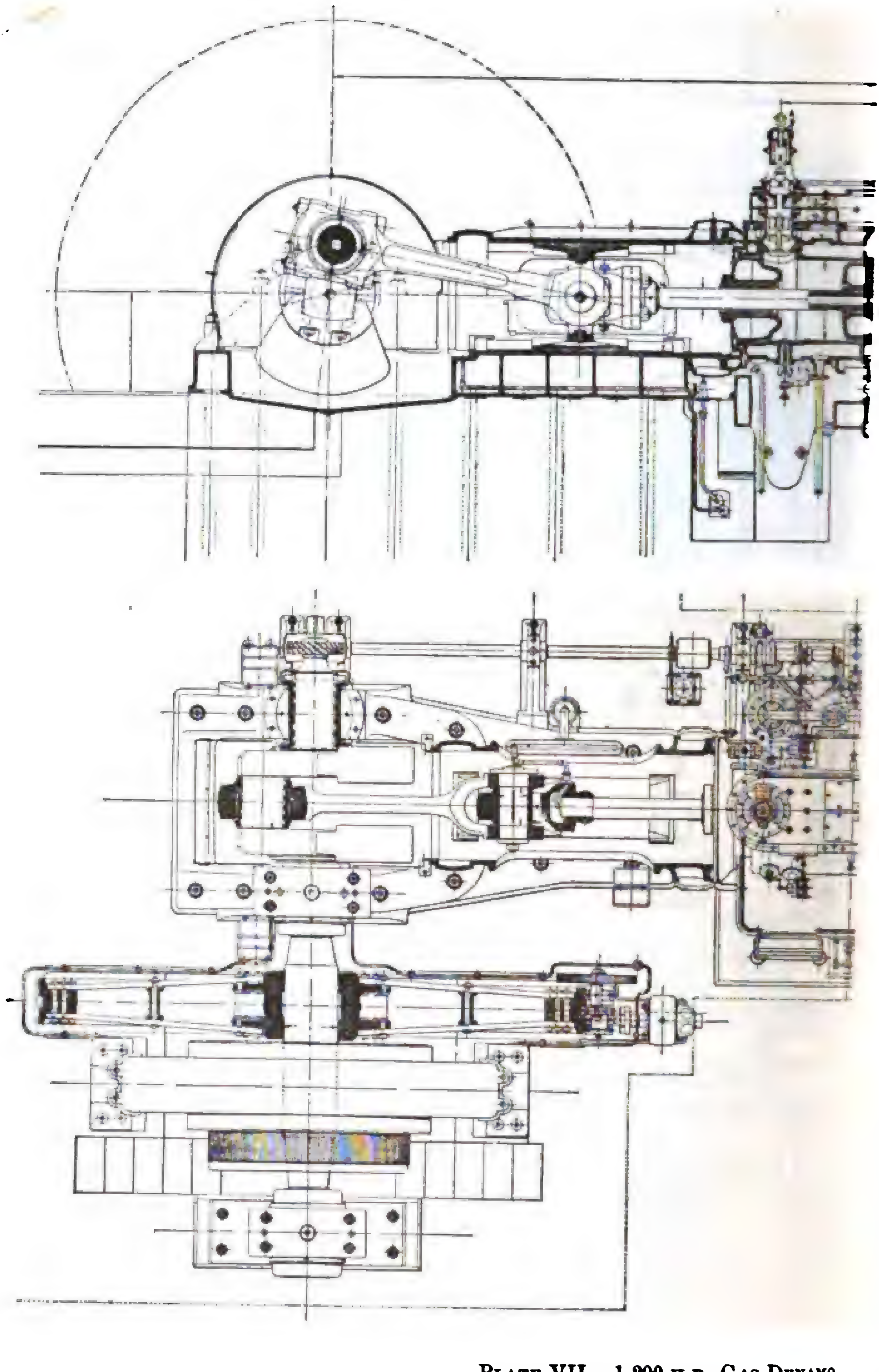
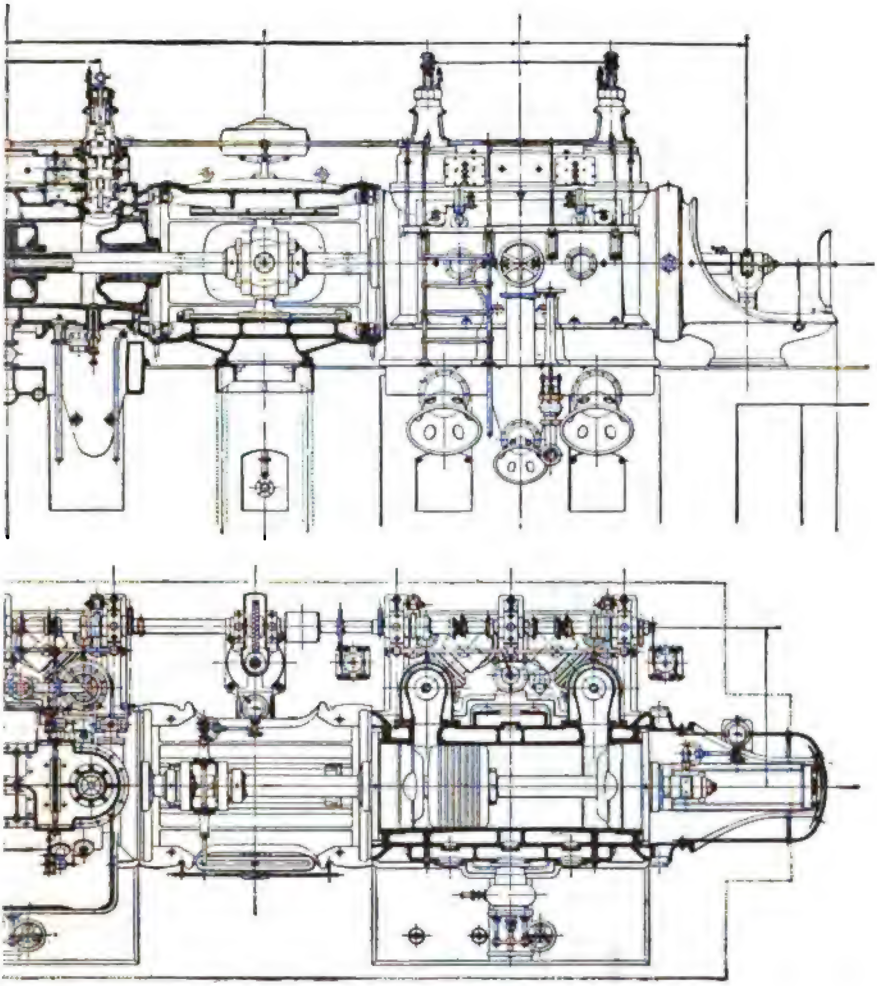


Plate VII.—1,200-h.p. Gas-Dynamo,



BY SCHÜCHTERMANN & KREMER.

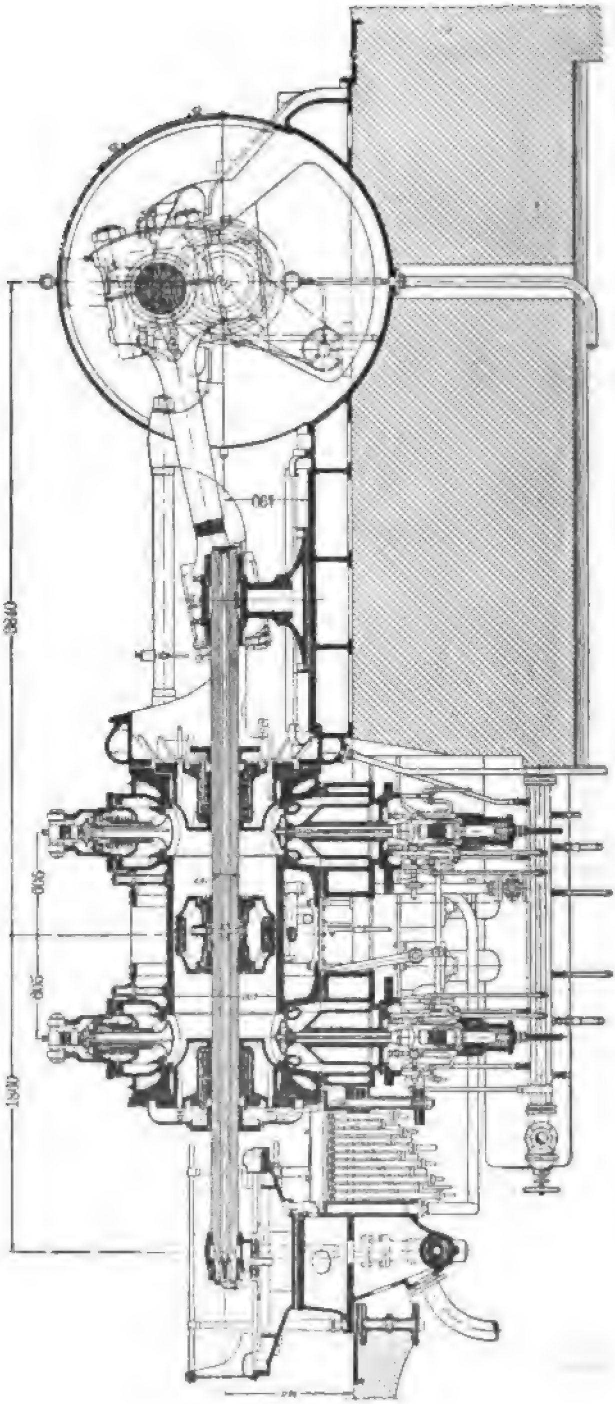


PLATE VIII.—REICHENBACH GAS-ENGINE, BY THE MASCHINENBAU-AKT.-GES. UNION. (Longitudinal Section.)

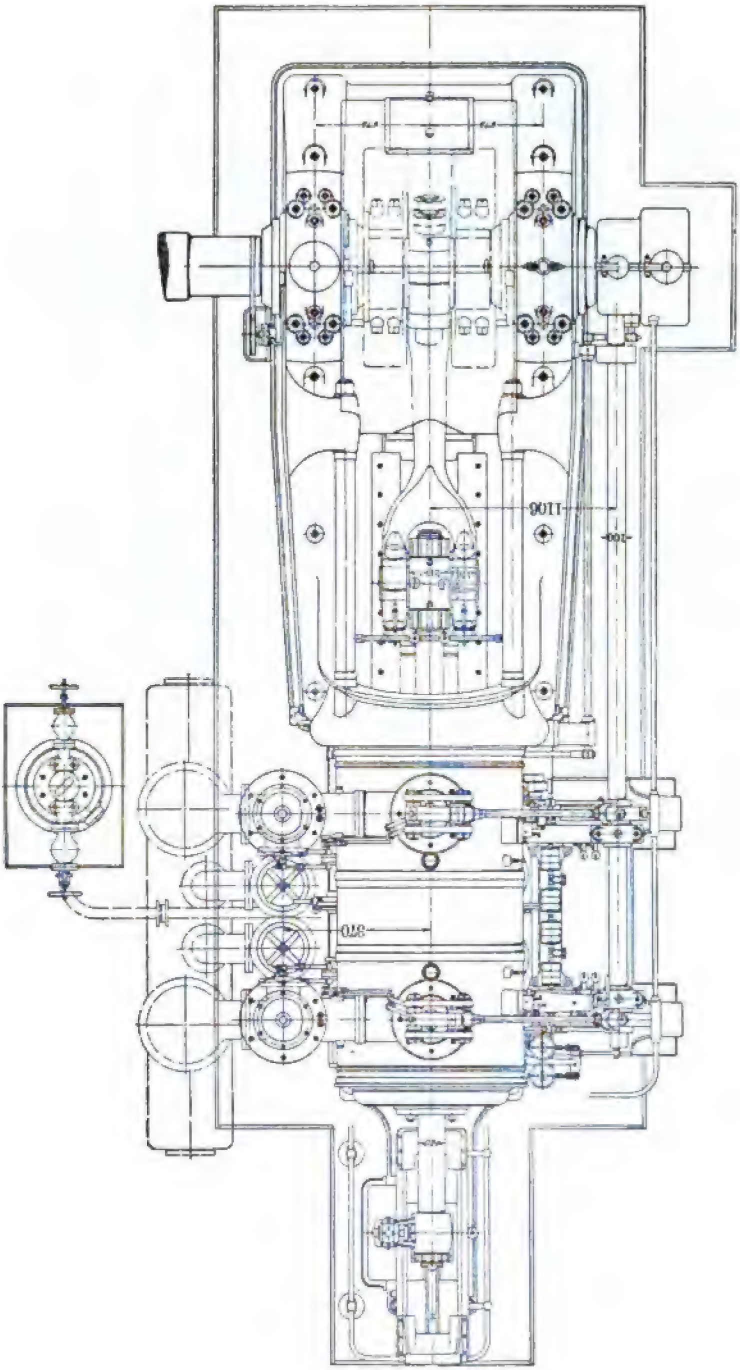


PLATE VIII.—REICHENBACH GAS-ENGINE, BY THE MASCHINENBAU-AKT.-GES. UNION. (Plan.)

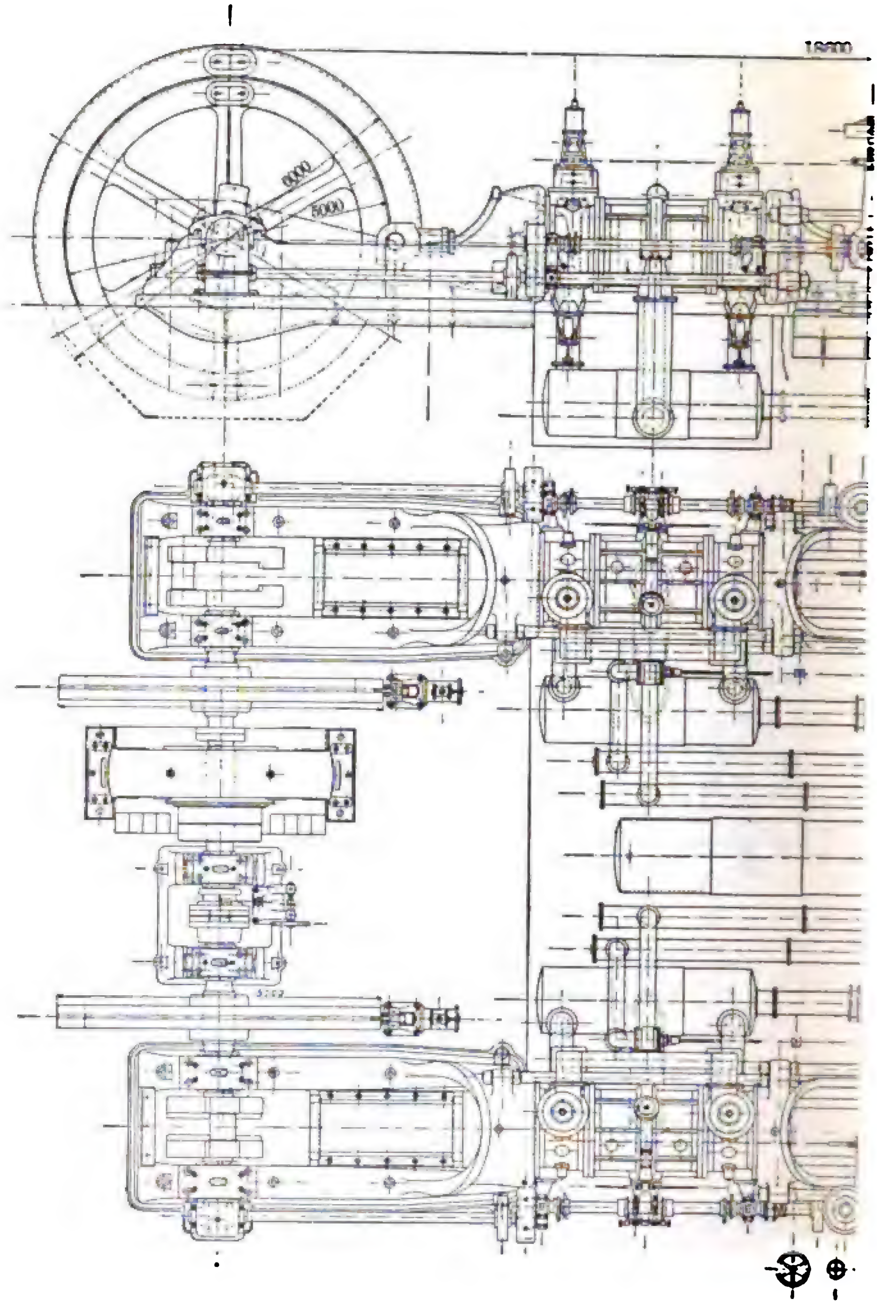
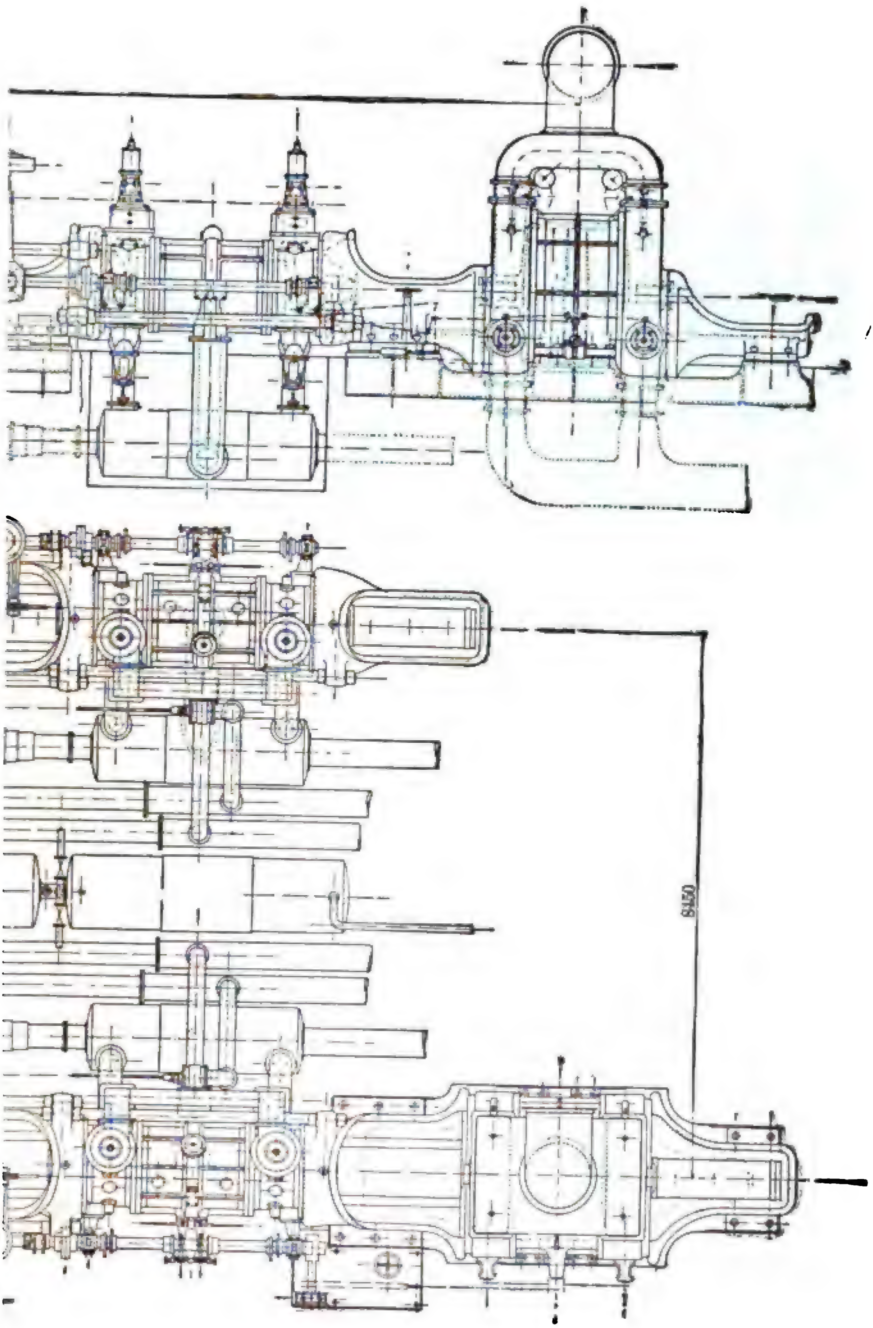


PLATE IX.—1,600-H.P. GAS-DYNAMO AND BLOWING-ENGINE,



BY THE DUISBURGER MASCHINENBAU-AKT.-GES.

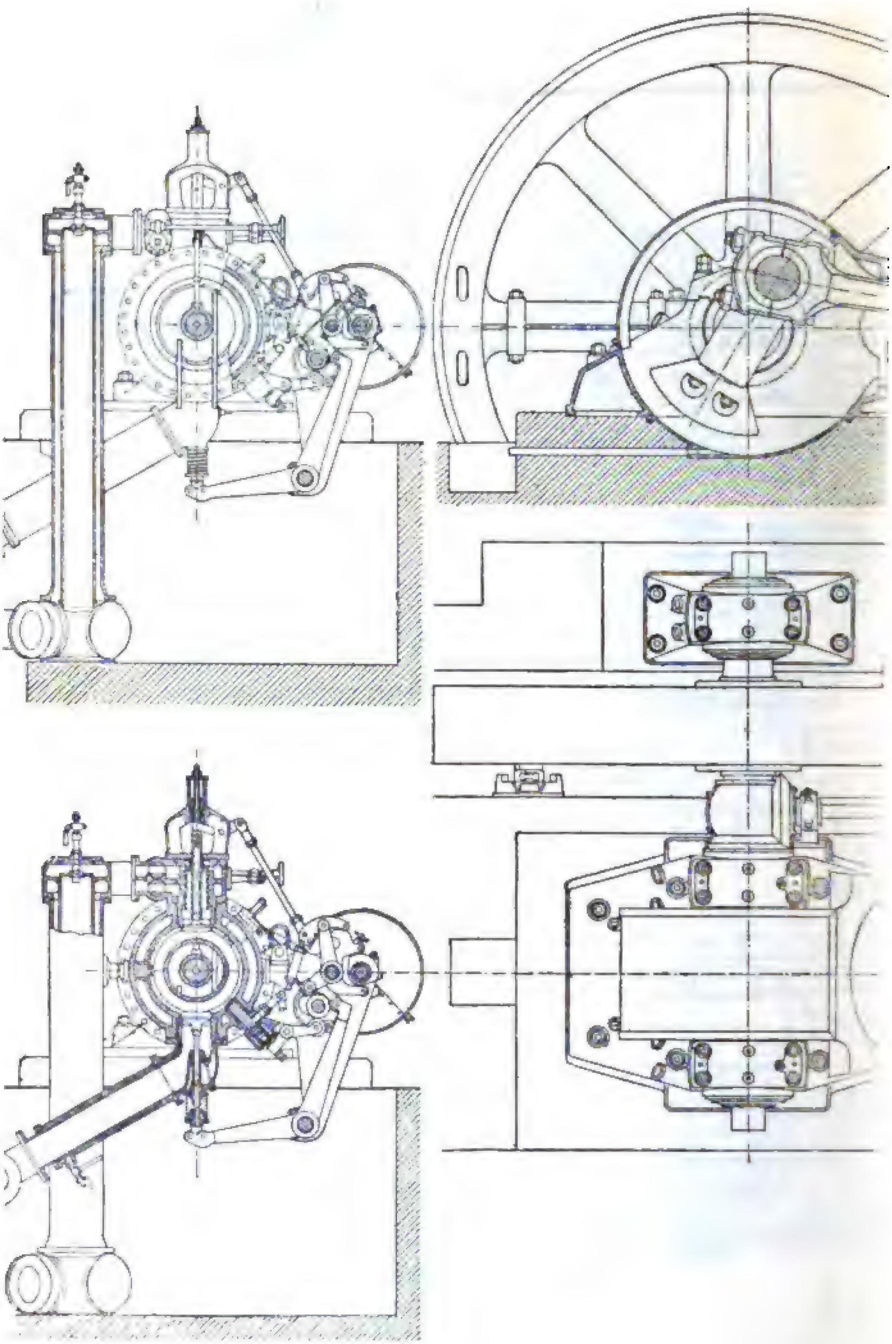
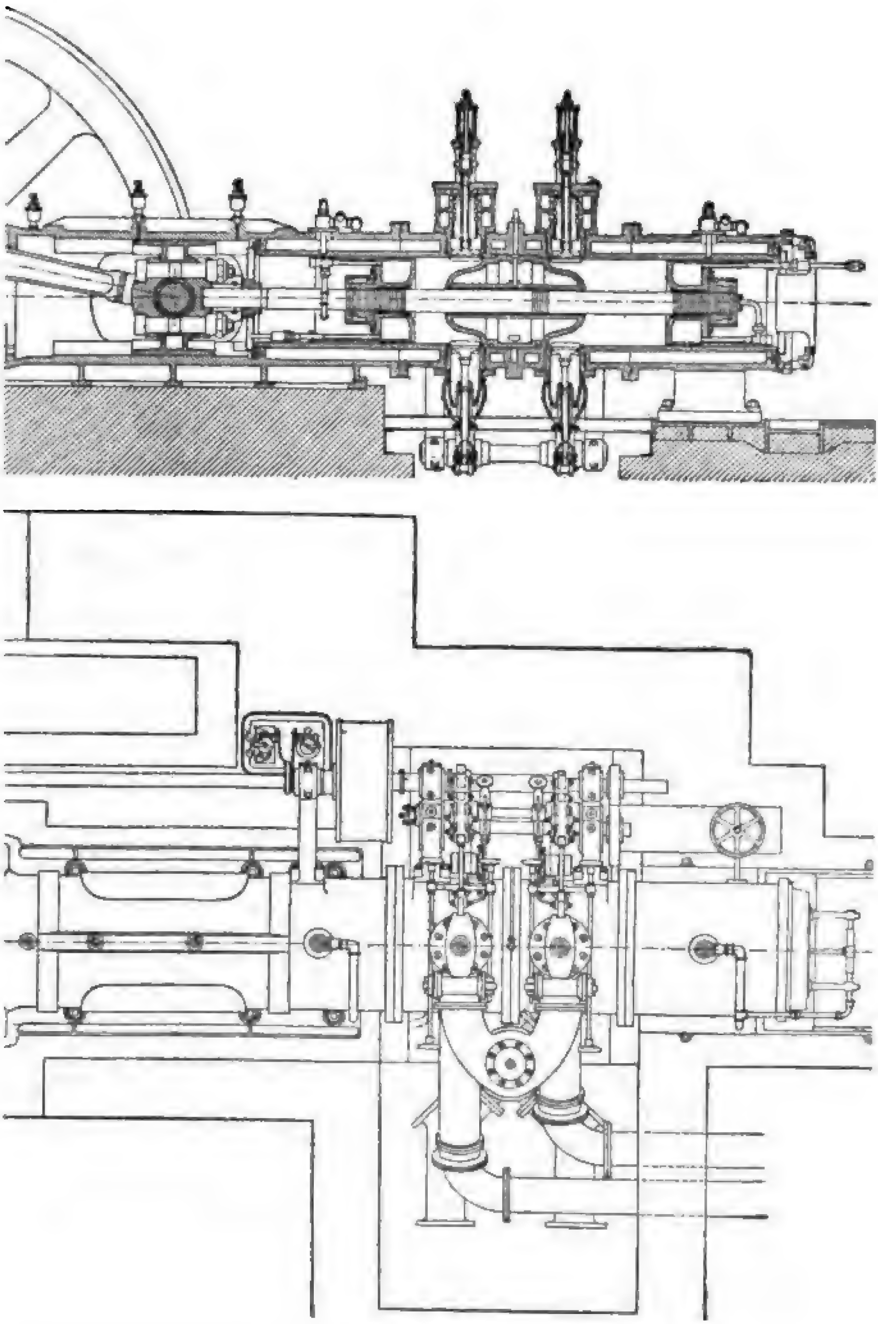


PLATE X.—DOUBLE-ACTING FOUR-CYCLE GAS-ENGINE, BY



THE DINGLER'SCHE MASCHINEN-FABRIK AKT.-GES.

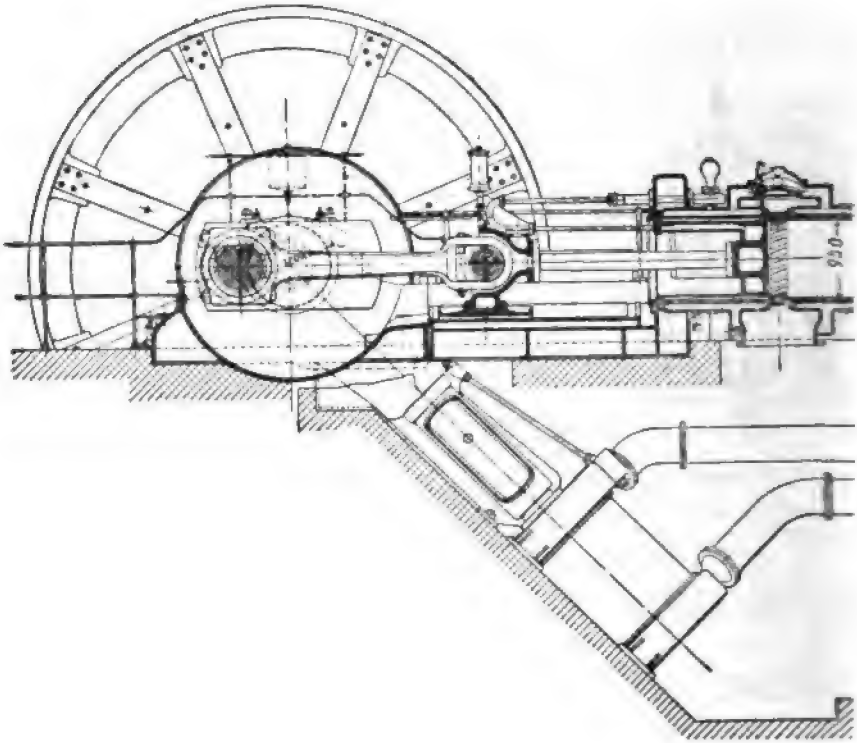
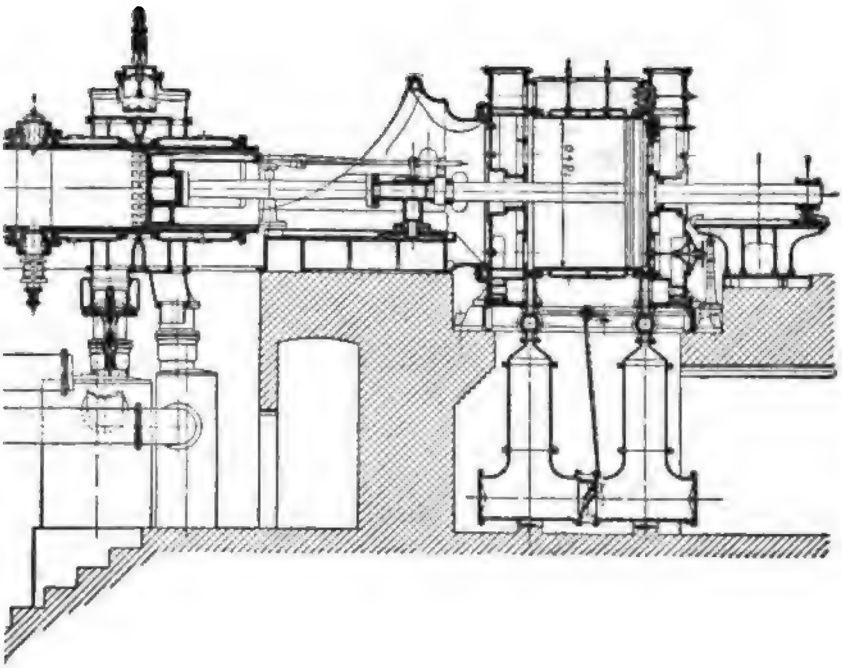


PLATE XI.—Two-Cycle Engine, Oechelhäuser System,



BY THE ASCHERSLEBENER MASCHINENBAU-AKT.-GES.

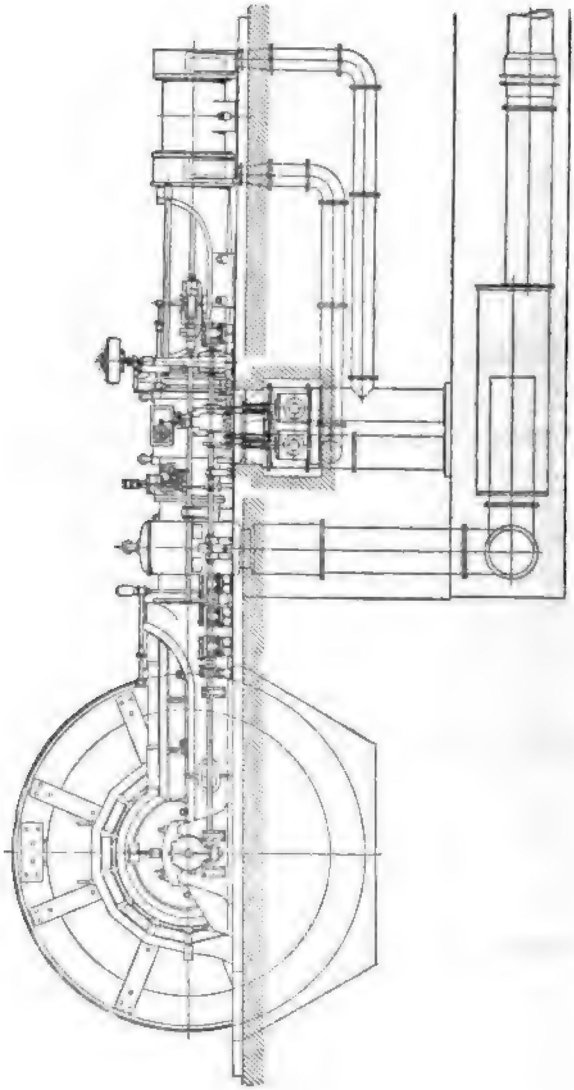


PLATE XII.—1,000-H.P. OECHELHÄUSER TWIN ENGINE, BY A. BORSIG. (Longitudinal Section.)

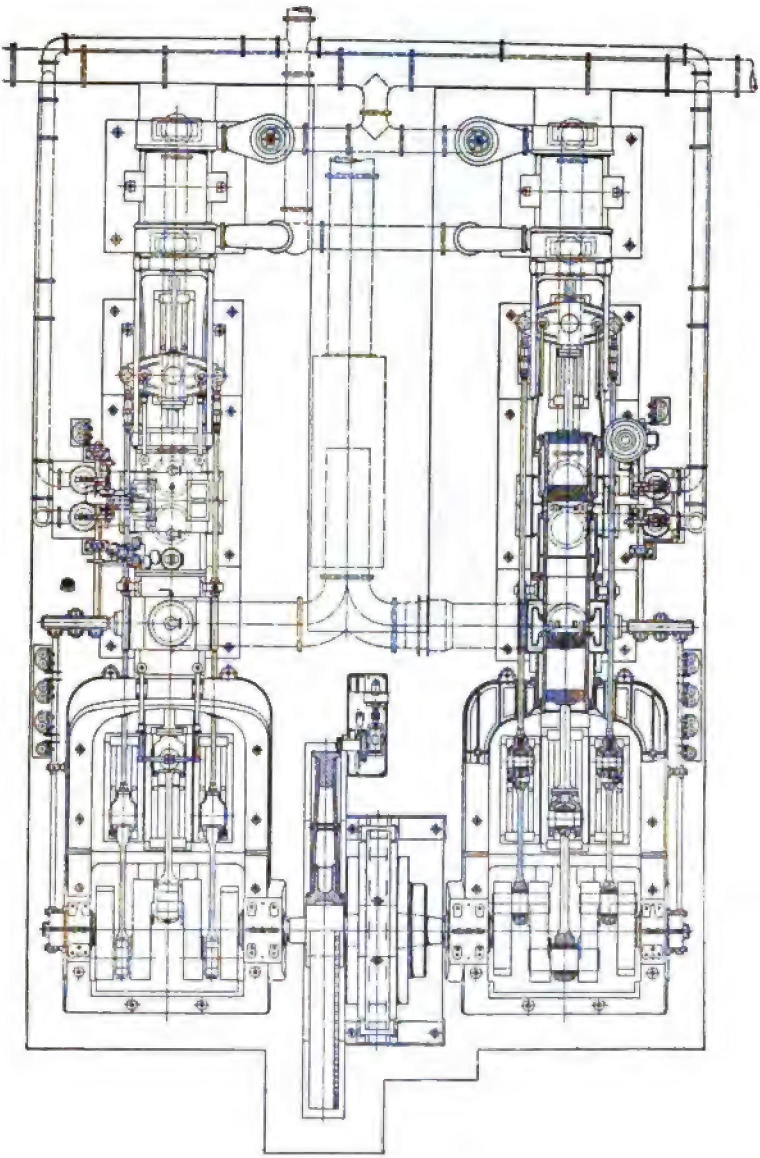


PLATE XII.—1,000-H.P. OECHELHÄUSER TWIN ENGINE, BY A. BORSIG. (Plan.)

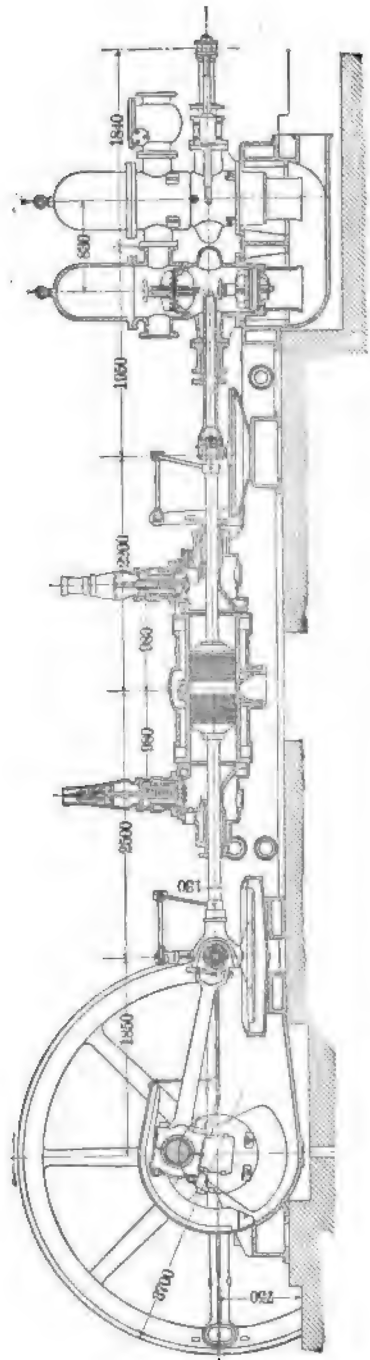


PLATE XIII.—ACCUMULATOR-PUMP WITH GAS-DRIVING, BY THE SIEGENER MASCHINENBAU-AKT.-GES. (Longitudinal Section.)

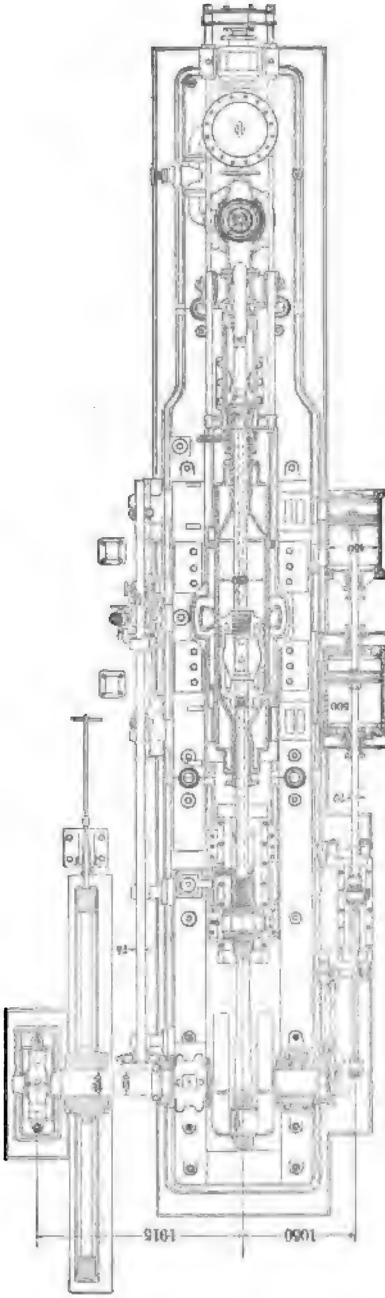


PLATE XIII.—ACCUMULATOR-PUMP WITH GAS-DRIVING, BY THE SIEGENER MASCHINENBAU-AKT.-GES. (Plan.)

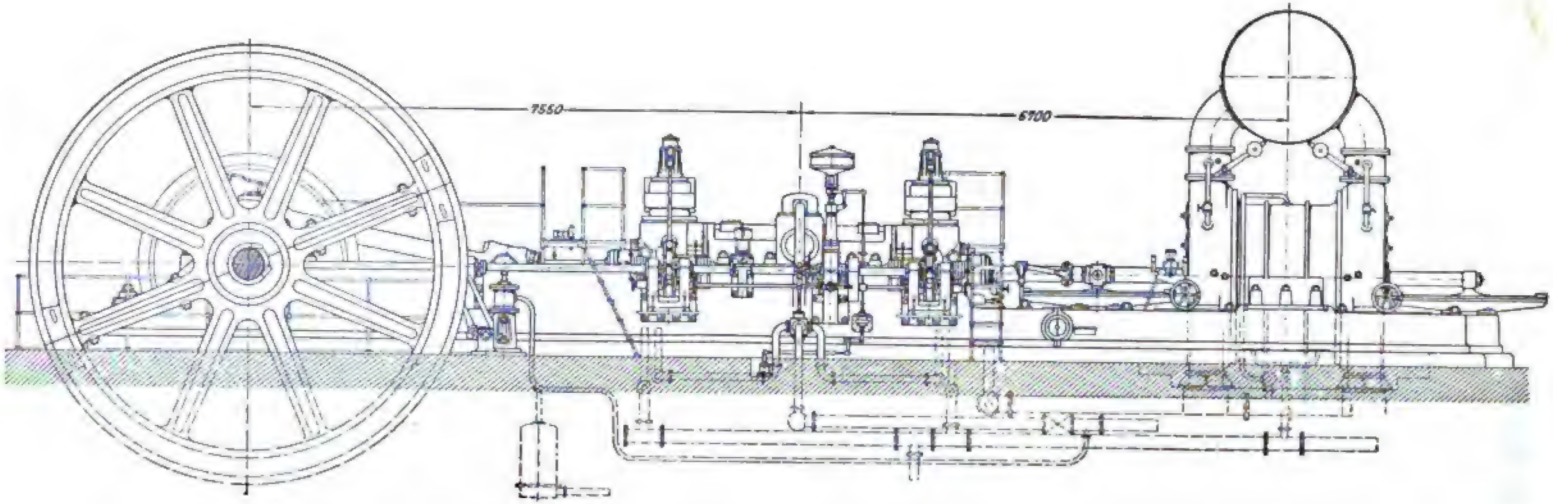


PLATE XIV.—TWIN BLAST-FURNACE BLOWING GAS-ENGINE, BY THE MASCHINENBAU-AKT.-GES. (Longitudinal Section.)

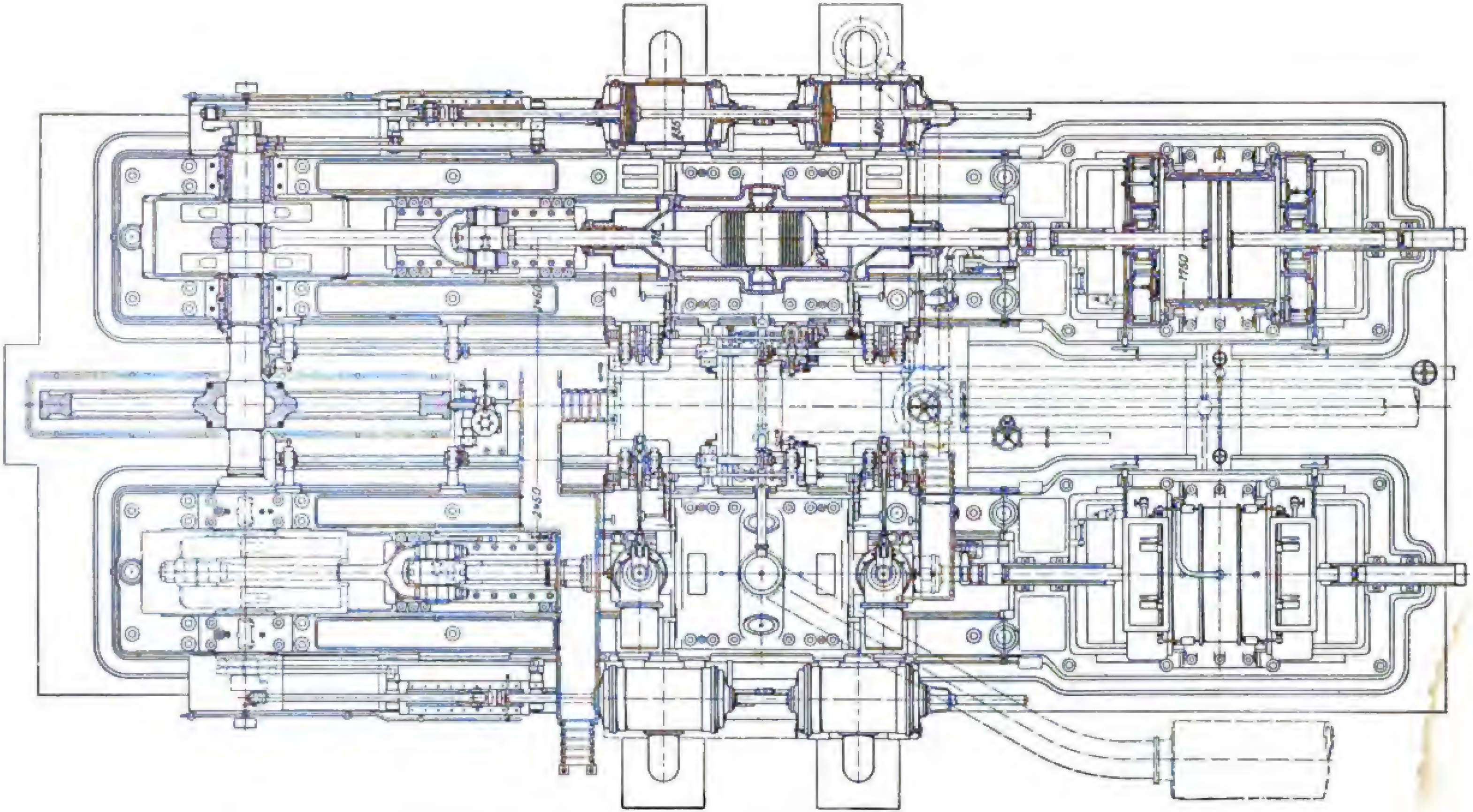


PLATE XIV.—TWIN BLAST-FURNACE BLOWING GAS-ENGINE, BY THE MASCHINENBAU-AKT.-GES. (Plan.)

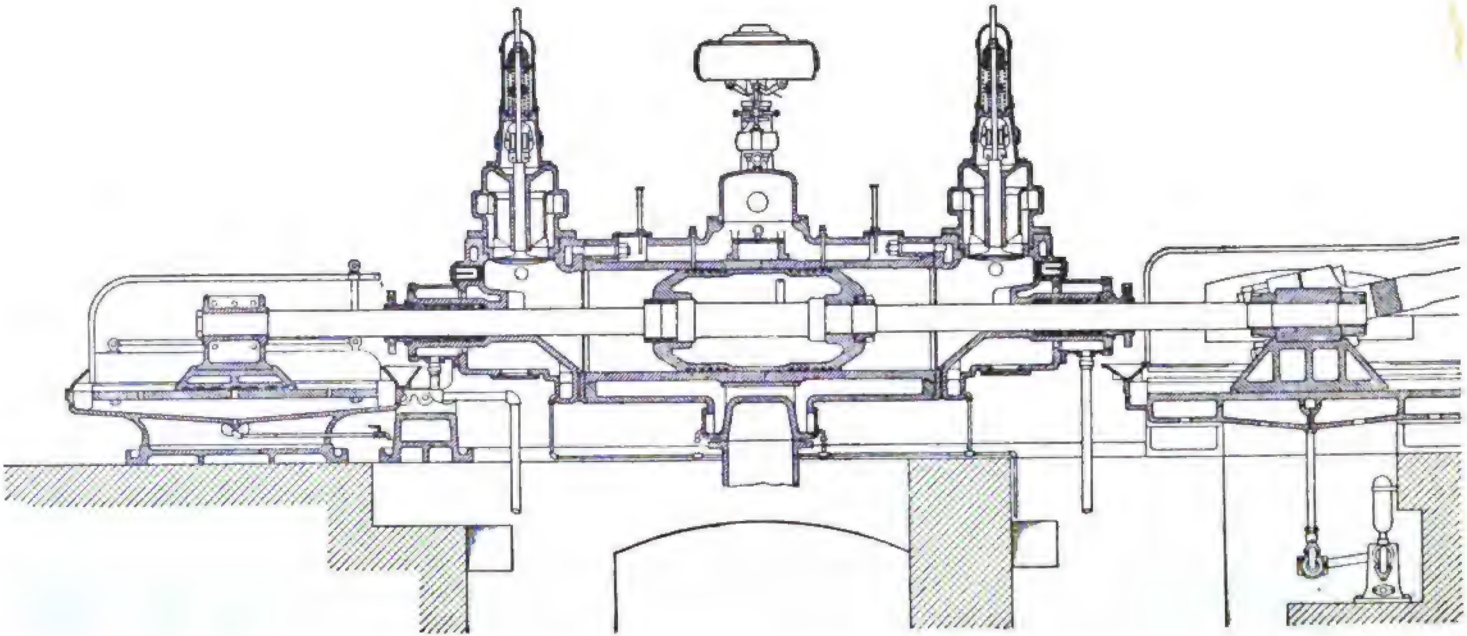


PLATE XV.—400-H.P. KÖRTING GAS-ENGINE, BY KÖRTING BROTHERS. (Longitudinal Section.)

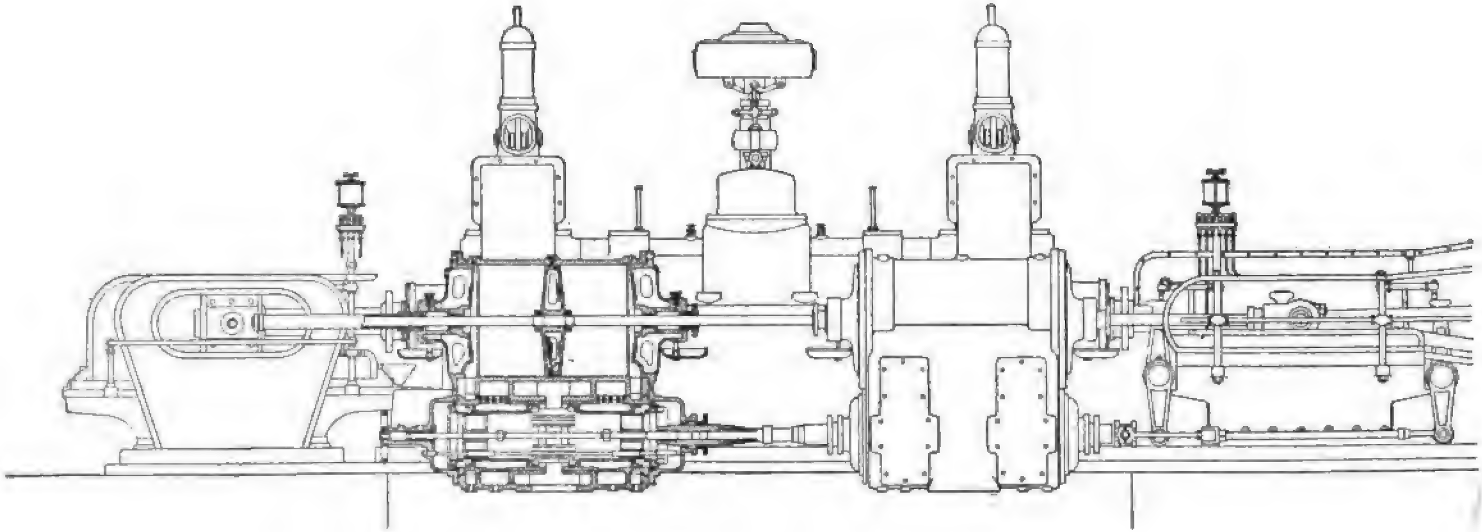


Plate XV.—400-h.p. Körting Gas-Engine, by Körting Brothers. (Longitudinal Section and Elevation.)

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